VOLUME 86 NO. SA1
JANUARY 1960
PART 1

JOURNAL of the

Sanitary Engineering Division

PROCEEDINGS OF THE

AMERICAN SOCIETY
OF CIVIL ENGINEERS

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SANITARY ENGINEERING DIVISION

Proceedings of the American Society of Civil Engineers

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Journal of the
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AEROBIC METABOLISM OF POTASSIUM CYANIDE

By John B. Nesbitt,[1] M. ASCE, H. Robert Kohl,[2]
and Elmer L. Wagner, Jr.[3] A.M. ASCE

SYNOPSIS

In an activated sludge system in which no mixed liquor suspended solids were wasted and in which CN^- served as the only source of carbon and nitrogen, it was found that (1) more than 99% of the CN^- was metabolized, (2) suspended solids were maintained, (3) approximately 98% of the cyanide-carbon was converted to CO_2, and (4) from 75% to 90% of the cyanide-nitrogen was converted to ammonia, nitrite, and nitrite.

INTRODUCTION

Inorganic cyanide wastes produced in the metal plating and metal hardening industries are said to be one of the most toxic wastes produced in industry. Small quantities of cyanide may be toxic to fish, while even smaller concentrations may interrupt the natural purification processes of a stream by killing the responsible microorganisms. Similar toxic effects have been observed on most biological sewage treatment processes.

Most present day cyanide disposal methods are chemical processes which are expensive because of the required purchase of either chemicals, electric

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current or heat and the necessary disposal of either sludge or toxic hydrogen cyanide gas.

Recently, however, the extreme versatility of a biological system in the treatment of industrial wastes was demonstrated by its adaption to a feed of sewage and complex metal cyanides containing 150 mg per l HCN or a feed of complex metal cyanides alone containing 160 mg per l HCN. This work was done on trickling filters in England by A. E. J. Pettet and E. V. Mills[4] of the British Water Pollution Research Laboratory and has resulted in the construction of a few experimental trickling filter plants for the treatment of cyanide wastes. These plants have proven to be more economical than present chemical treatment methods.

Most of the fundamental research on the biological metabolism of inorganic cyanide has been done by the British Water Pollution Research Laboratory in Stevenage, England. In the work by Pettet and Mills,[4] the effluent cyanide from the filters was less than 0.5 mg per l HCN both with and without sewage feed. In the experiments with sewage feed, the oxygen-absorbing power of the filter effluent, as measured by the permanganate value, increased with increases in the concentration of cyanide in the applied sewage. The same increase in cyanide concentration caused a decrease in the nitrate plus nitrite concentration in the effluent with total cyanide nitrogen recoveries varying between 50 and 100 percent.

More recently this same laboratory reported[5] further studies on the biological metabolism of sodium cyanide by both trickling filters and activated sludge. The trickling filter, fed from 66 g to 155 CN^- per cu yd per day in base exchange softened water containing 5 mg per l peptone, removed in excess of 98% of the cyanide. Approximately 65% of the nitrogen was recovered as ammonia and nitrite plus nitrate with 95% of this recovery being ammonia. The activated sludge unit contained 52,000 mg per l mixed liquor suspended solids and was fed, once each day, solutions of sodium cyanide containing cyanide in concentrations varying from 29 to 173 mg per l. These solutions provided cyanide feed ranging from 22 to 130 mg per l per day. Essentially 100% of the cyanide was removed at all feed rates, while total nitrogen recoveries varied from 85% to 110%. Of the total nitrogen recovered, the percentage recovered as ammonia increased from 19% to 97% while the percentage recovered as nitrite plus nitrate decreased from 81% to 6% as the cyanide feed increased.

During the above-mentioned work, H. A. Painter and G. C. Ware[6] isolated from the trickling filter a related gram-positive organism, provisionally classified among the actinomycetaceae, which was capable of converting cyanide almost qualitatively to ammonia. The organism was aerobic, a strict autotroph, lived ideally within a pH range of 7.5 to 9.0, and was found predominantly in the top 1 ft of the 6-ft deep filter.

The above work indicated that inorganic cyanides were amenable to biological treatment. It was the purpose of this research to confirm and extend the British work by studying the metabolism of potassium cyanide in the absence of sewage in a laboratory scale "no waste" activated sludge system. More specifically the study included:

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[4] "Biological Treatment of Cyanides with and without Sewage," by Pettet, A. E. J. and Mills, E. V., Journal of Applied Chemistry, Vol. 40, p. 434, 1954.

[5] Department of Scientific and Industrial Research (British), Water Pollution Research, 1957, Her Majesty's stationary office, London, p. 67, 1958.

[6] "Bacterial Utilization of Cyanide," Nature, Vol. 175, p. 900, 1955.

1. Experiments to determine the equilibrium weight of mixed liquor suspended solids for two different cyanide feed rates. These experiments included tests to determine the percentage of feed cyanide actually metabolized by the microorganisms.
2. The running of nitrogen and carbon balances in the above two systems.

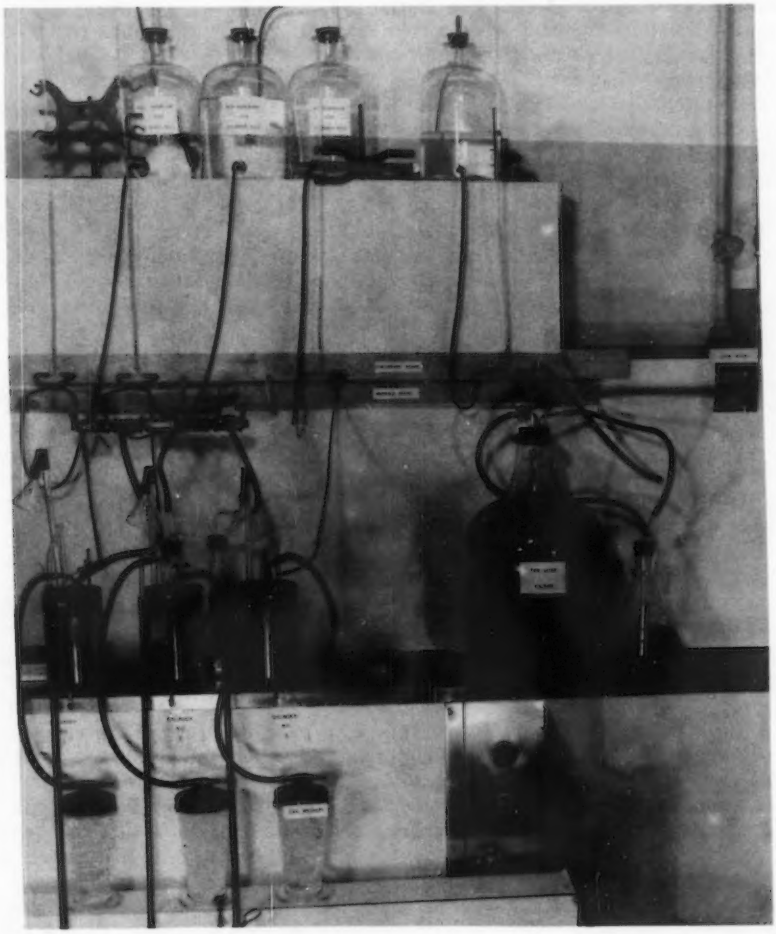

FIG. 1.—EXPERIMENTAL APPARATUS

APPARATUS AND EXPERIMENTAL PROCEDURE

Apparatus.—The apparatus used to maintain the activated sludge cultures in this research is shown in Figs. 1 and 2. It consisted of two, stoppered, 3-l cylinders held in place in a constant temperature water bath at 24°C. Attached to

each cylinder through the stopper was a cyanide-feed hose, an air-supply hose containing a carborundum air diffuser, and an exhaust-air hose. The exhaust-air hose was attached to a gas washer containing sodium hydroxide at pH 11+ to collect any hydrogen cyanide gas blown from the system.

The potassium cyanide feed apparatus is shown in detail in Fig. 2. When the arm of the clock motor moved to position A, valve a (rubber hose from the cyanide reservoir connected to a stationary glass tee) opened, allowing a known

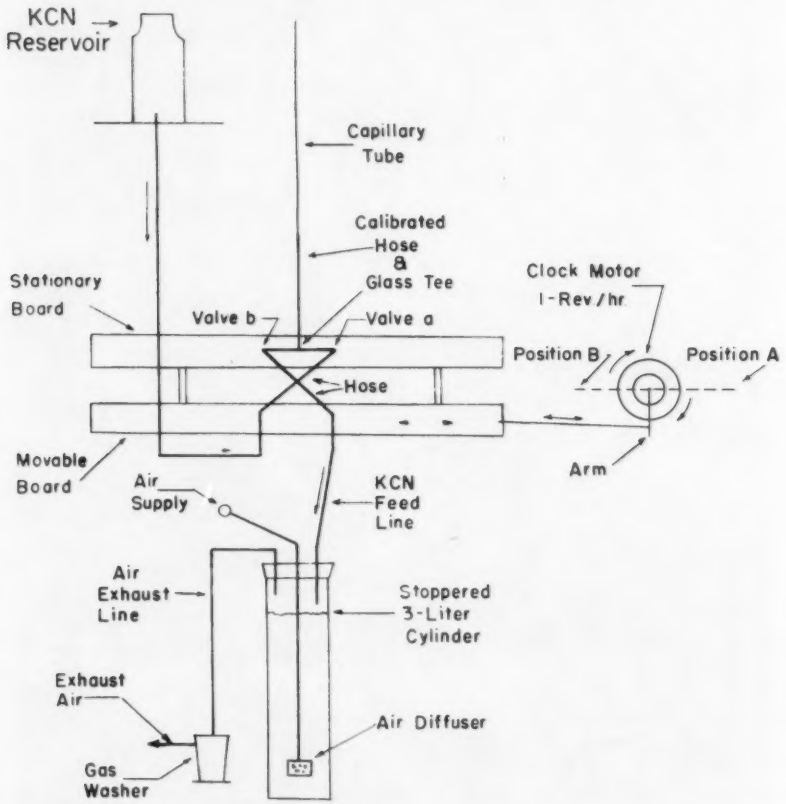

FIG. 2.—EXPERIMENTAL APPARATUS

quantity of potassium cyanide to flow into the glass tee and hose. In this position valve b was closed. When the arm on the clock motor moved to position B, valve b opened, allowing the known quantity of potassium cyanide to flow into the cylinder. A capillary tube was used on the end of the calibrated hose and glass tee so that varying liquid levels in the cyanide reservoir did not appreciably affect the hourly volume of cyanide fed.

The 10-l culture apparatus shown in Fig. 1 was identical to that of the cylinders except for the volume of the culture container.

Experimental Procedure.—In order to acclimate activated sludge to potassium cyanide, 10-l of normal activated sludge were first developed by aerating

100 ml of primary sewage sludge from the State College Sewage Treatment Plant in 10 l of tap water. The culture was settled for 1 hr daily, following which 5 l of clear supernatant were decanted and replaced with tap water and 100 ml of primary sludge. No solids were withdrawn from the system at any time.

After a culture of activated sludge was developed (mixed liquor suspended solids concentration of 2000 mg per l), 10 mg CN^- (1.0 mg per l in mixed liquor) was added daily in hourly increments. The cyanide residual was determined daily on the settled effluent and when no cyanide residual was found, the cyanide was increased to 20 mg CN^- per day (2.0 mg per l in mixed liquor). About 7 days were required for the culture to completely metabolize the 10 mg CN^- feed and produce no residual cyanide. This procedure was followed until the daily cyanide feed was 400 mg CN^-. At this point the 100-ml sludge feed and the tap water were gradually replaced with dilution water containing 22.5 mg per l $MgSO_4 \cdot 7E_2O$, 27.5 mg per l $CaCl_2$, 0.25 mg per l $FeCl_3 \cdot 6H_2O$, 85 mg per 1 $Na_2HPO_4 \cdot 7H_2O$, and sufficient NaH_2PO_4 to bring the pH to 7.0. Thus, by this replacement, the cyanide became the only source of carbon and nitrogen for the culture. The cyanide reservoir was also buffered to pH 8.9 as experience proved this necessary to keep the system operating in the pH range 7.5 to 8.5.

When the 10-l culture was metabolizing 400 mg CN^- per day and producing no cyanide in the effluent, 1 l of the mixed liquor was transferred to each of two 3-l cylinders and diluted to 3 l with the buffered dilution water. For the duration of the experiment, one cylinder was fed 60 mp CN^- per day and the other 120 mg CN^- per day through the hourly feed system.

The following was a schedule of the normal daily operating procedure:

1. Cut off the cyanide feed and air supply and allow each cylinder to settle for one hour;
2. Decant 1 l of the settled liquor (effluent) from each cylinder;
3. Filter the effluent through clean sand, wash the sand with dilution water and return the dilution water and washed solids to their respective cylinder;
4. Fill each cylinder to the 3-l mark with dilution water and resume aeration and the cyanide feed;
5. Determine the cyanide residual and the pH of the effluent; and
6. Determine the amount of cyanide in the gas washers.

Approximately once a week samples of mixed liquor were withdrawn for the determination of suspended solids and periodically for organic nitrogen.

Daily measurements of ammonia, nitrite, and nitrate nitrogen were made on the effluent prior to filtration during the time a nitrogen balance was being made. At this same time the effluent air was passed through 4% boric acid in the gas washer in order to trap any volatile ammonia.

When a carbon balance was being run the air supply to each cylinder was passed through a soda-lime column to remove all incoming carbon dioxide (Fig. 3). The exhaust air was then passed through a Fisher-Milligan gas washer containing sodium hydroxide which collected the carbon dioxide given off during the metabolism. Barium chloride and moisture traps were placed between the soda-lime column and the culture tube and after the gas washer to indicate whether any carbon dioxide passed either device. A water seal was at the end of the system to eliminate the entrance of atmospheric carbon dioxide.

All analyses were made according to the established procedures[7] except for

[7] Amer. Pub. Health Assn., Amer. Water Works Assn.

mixed liquor suspended solids and carbon dioxide trapped in the gas washer. Suspended solids were determined using the Millipore filter technique described[8] by R. S. Engelbrecht and R. E. McKinney. Carbon dioxide was precipited from a 50 ml portion of the gas washer by 0.2 N barium chloride. The barium carbonate precipitate was filtered through a fiber glass filter, dried at 700°C in a muffle furnace and weighed.

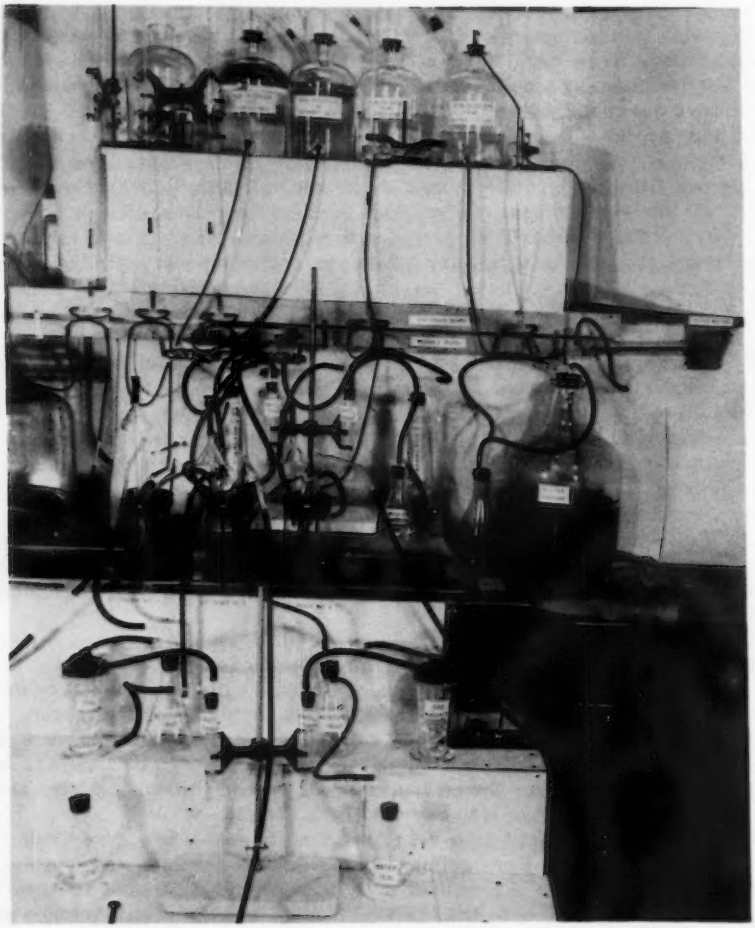

FIG. 3.—EXPERIMENTAL APPARATUS

[8] "Membrane Filter Method Applied to Activated Sludge Suspended Solids Determinations," by R. S. Engelbrecht and R. E. McKinney, Sewage & Industrial Wastes, Vol. 28, November, 1956, p. 1321.

RESULTS

Mixed Liquor Suspended Solids.—Table 1 and Fig. 4 show the cyanide feed and suspended solids concentrations throughout the 185 days of operation.

During the first 40 days of operation, mixed liquor suspended solids were determined daily and the liter of supernatant liquor decanted daily from each cylinder was discarded. Using this procedure, the suspended solids were quite erratic and showed a steady decline to concentrations of approximately 130 mg per l and 100 mg per l in Cylinders 2 and 3, respectively. There was no indication that an equilibrium would be obtained.

From the 40th to 115th day of operation, less frequent suspended solids tests were taken while the daily effluent was filtered through sand and the

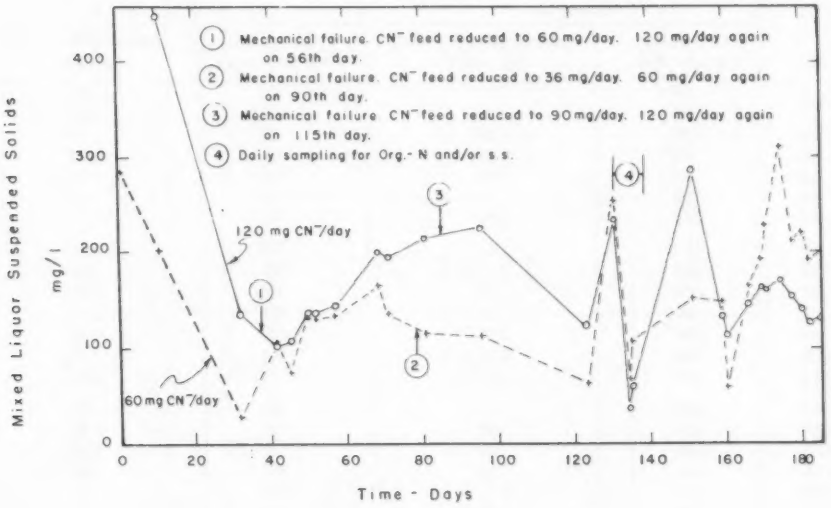

FIG. 4.—MIXED LIQUOR SUSPENDED SOLIDS

solids returned to the system. During this period the suspended solids concentrations increased to approximately 220 mg per l and 110 mg per l in Cylinders 2 and 3, respectively. However, due to mechanical difficulties which caused excessive cyanide feed, no cyanide feed, or insufficient aeration, it was impossible to maintain any consistent suspended solids concentrations during this period.

The cyanide feed concentration remained normal from the 115th day to the end of the experiment; however, the results of suspended solids determinations were somewhat erratic until the 166th day. These erratic results undoubtedly were caused by daily sampling for organic nitrogen and/or suspended solids from the 131st to 138th days and an appreciable accumulation of solids on the cylinder walls. This accumulation of solids had been noticed prior to the 115th day and could have been partially responsible for the erratic data prior to that time. From the 166th day to the end of the experiment the cylinder walls were washed daily and more consistent suspended solids results were obtained.

These results showed the suspended solids to be approximately 150 mg per l and 220 mg per l in cylinders 2 and 3 respectively.

Data[9] taken by H. Robert Kohl during the above operating period showed that during normal operation no residual cyanide could be detected in either cylinder and that no more than 0.1 to 0.3 mg per day of cyanide was collected in the gas washers. When mechanical failures upset the normal operation of the system, cyanide residuals as high as 69.0 mg per l were obtained in the cylinders and as much as 9.1 mg per day of cyanide were collected in the gas washers.

Nitrogen Balance.—At intervals between the 115th and 185th day, nitrogen

TABLE 1.—CYANIDE FEED, SUSPENDED SOLIDS DATA

Day	Cylinder No. 2		Cylinder No. 3	
	CN^- feed, mg per day	Suspended solids, mg per l	CN^- feed, mg per day	Suspended solids, mg per l
1	60	710	60	284
11	120	444	60	201
33	120	132	60	30
42	60[a]	102	60	107
45	75	109	60	74
49	105	139	60	136
52	105	138	60	131
57	120	142	60	136
68	120	200	60	166
71	120	196	60	138
81	120	212	36[b]	113
96	102[c]	226	60	112
123	120	121	60	63
131	120	234[d]	60	252[d]
134	120	38	60	70
135	120	60	60	108
152	109	288	58	152
158	120	134	60	148
160	120	112	60	60
166	120	146	60	166
169	120	166	60	192
171	120	160	60	228
174	120	170	60	310
177	120	154	60	230
180	120	140	60	220
182	120	126	60	192
185	120	130	60	200

[a] Mechanical failure required the reduction of the CN^- feed to 60 mg per day on the 37th day. It returned to 120 mg per day on the 56th day. [b] Mechanical failure required the reduction of the CN^- feed to 36 mg per day on the 78th day. It returned to 60 mg per day on the 90th day. [c] Mechanical failure required the reduction of the CN^- feed to 90 mg per day on the 85th day. It returned to 120 mg per day on the 115th day. [d] Daily sampling for Org. -N and/or S. S. 131st to 140th days.

[9] "The Aerobic Metabolism of Potassium Cyanide by the Activated Sludge Process" by Robert H. Kohl, Master's Thesis, The Pennsylvania State Univ., January, 1959.

TABLE 2.—NITROGEN RECOVERY DATA, 1st PERIOD

Day	Cylinder No. 2					Cylinder No. 3				
	NH_3-N, mg per 1	NO_2-N, mg per 1	NO_3-N, mg per 1	N-gain, mg	CN-N fed, mg	NH_3-N mg per 1	NO_2-N, mg per 1	NO_3-N, mg per 1	N-gain, mg	CN-N fed, mg
131	8.1	27.0	6.3	—	—	4.3	12.8	8.4	—	—
132	10.0	28.5	6.4	57.8	63.5	3.8	14.3	8.9	33.3	33.6
133	7.8	31.5	5.8	48.7	61.0	3.4	15.0	8.7	29.0	32.3
134	6.1	33.0	6.9	51.2	61.0	4.5	15.3	8.4	32.6	32.3
135	5.0	30.5	5.9	37.3	63.5	3.9	13.5	9.2	26.7	33.6
136	5.2	25.5	6.7	34.2	61.0	4.3	12.0	9.1	26.5	32.3
137	5.6	26.5	7.0	39.9	59.0	4.1	9.8	10.7	22.9	31.4
138	4.5	33.5	7.2	64.8	59.0	3.3	12.8	9.6	31.0	31.4
139	4.6	32.0	7.4	41.4	59.0	3.7	13.0	10.1	29.2	31.4
140	4.1	33.5	8.0	49.0	59.0	3.8	13.8	10.0	29.3	31.4
				424.3	546.0				260.5	289.7
Average	6.1	30.1	6.8			3.9	13.2	9.3		
% of Total	14.2	70.0	15.8			14.7	50.0	35.3		

% recovery = $\frac{424.3}{546.0} \times 100$

= 77.7%

% recovery = $\frac{260.5}{289.7} \times 100$

= 90.0%

TABLE 3.—NITROGEN RECOVERY DATA, 2nd PERIOD

Day	Cylinder No. 2					Cylinder No. 3				
	NH_3-N, mg per 1	NO_2-N, mg per 1	NO_3-N, mg per 1	N-gain, mg	CN-N fed, mg	NH_3-H mg per 1	NO_2-N, mg per 1	NO_3-N, mg per 1	N-gain, mg	CN-N fed, mg
154	3.0	31.5	10.6	—	—	1.1	7.5	17.7	—	—
155	3.1	32.0	12.0	51.2	64.6	1.3	8.3	19.2	39.1	32.5
156	2.6	34.5	11.3	51.0	64.6	0.0	7.0	22.6	32.0	32.5
157	2.5	37.5	10.7	50.0	64.6	0.3	7.0	21.0	24.9	32.5
158	2.5	36.5	11.5	50.0	67.5	0.0	3.0	22.5	19.5	33.8
159	3.0	33.0	11.8	48.0	64.6	1.5	5.3	20.8	32.0	33.8
160	3.5	32.0	10.0	41.0	64.6	0.0	4.1	19.3	14.5	21.6
161	3.4	40.0	11.3	74.5	64.6	0.2	5.0	18.2	23.4	33.8
162	3.7	33.0	9.7	25.0	64.6	0.5	4.1	19.0	23.9	33.8
163	0.0	32.0	12.8	44.2	32.8	0.8	6.0	20.8	36.0	34.7
164	4.7	24.0	12.0	32.0	62.0	1.0	5.5	21.3	28.5	32.0
165	6.0	29.0	10.3	54.9	67.5	1.2	5.7	22.2	31.4	34.7
166	6.8	30.5	10.3	53.2	64.6	1.0	4.0	25.0	31.9	33.4
167	8.4	30.0	12.0	64.5	67.5	1.3	6.6	21.0	33.7	34.7
168	8.0	24.0	10.0	24.0	64.6	1.6	5.8	22.4	26.6	33.4
169	6.8	28.5	13.7	64.0	64.6	1.7	5.8	23.0	33.8	33.4
				707.5	943.3				431.0	499.3
Average	4.3	31.8	11.3			0.8	5.7	21.0		
% of Total	9.1	67.0	23.9			2.9	20.7	76.4		

% recovery = $\frac{707.5}{943.3} \times 100$ = 75.0%

% recovery = $\frac{431.0}{499.3} \times 100$ = 86.3%

recovery tests were conducted on the effluent of both cylinders to determine the weights of ammonia, nitrite and nitrate produced through the cyanide metabolism. Tables 2 and 3 list the weights and percentages of these products found and also the total percentage nitrogen recovered for each of the cultures during the two periods.

For the first period (Table 2) nitrogen recovery in the effluent of Cylinder No. 2 averaged 14.2% ammonia, 70.0% nitrite, 15.8% nitrate, for a total nitrogen recovery of 77.7%. A 90.0% nitrogen recovery was obtained in the effluent of Cylinder No. 3 with a 14.7% as ammonia, 50.0% as nitrite, and 35.3% as nitrate.

During the second nitrogen recovery period (Table 3), 75.0% of the nitrogen added was recovered in the effluent of Cylinder No. 2, with 9.1% as ammonia, 67.0% as nitrite, and 23.9% as nitrate. During this same period 86.3% of the nitrogen fed to Cylinder No. 3 was recovered, with the effluent averaging 2.9% ammonia, 20.7% nitrite, and 76.4% nitrate.

At no time during the nitrogen recovery tests was an appreciable amount of ammonia recovered in the gas washers.

TABLE 4.—SUSPENDED SOLIDS-ORGANIC NITROGEN DATA

Day	Cylinder No. 2			Cylinder No. 3		
	Suspended solids, mg per 1	Organic-N, mg per 1	N/suspended solids, %	Suspended solids, mg per 1	Organic-N, mg per 1	N/suspended solids, %
134	—	—	—	70.0	4.5	6.5
135	60	6.0	10.0	108	6.9	6.4
166	146	13.2	9.0	166	11.4	6.9
169	166	13.0	8.1	192	13.5	6.9
171	170	13.8	8.1	310	16.6	5.4
177	154	13.2	8.6	230	14.4	6.3
Average			8.6			6.5

Organic nitrogen tests were conducted at various times throughout the experiment. Table 4 lists the organic nitrogen found, suspended solids at the time of sampling, and the percentage nitrogen by weight in the suspended solids. The percentage organic nitrogen averaged 8.6% and 6.5% in Cylinders 2 and 3, respectively.

Carbon Balance.—Table 5 gives carbon recovery data from a 13 day period for two, 3-l cylinders being fed 117 mg CN^- per day and 57 mg CN^- per day, respectively. The cylinders were similar to those used in the initial 185-day run; however, the data were collected in a subsequent run.

DISCUSSION

The data reported under "Mixed-Liquor Suspended Solids" indicate that when the systems were not upset by a mechanical failure, 99+% of the cyanide fed to the systems was metabolized by the organisms. This fact was corroborated by the carbon recovery data which indicated that 97.9% of the cyanide carbon fed to either system was recovered as carbon dioxide.

The same data indicate that the determination of an equilibrium weight of mixed-liquor suspended solids for specific cyanide feed rates was inconclusive. Aroung the 115th day of operation the solids concentration appeared to

reach an equilibrium at 220 mg per l and 110 mg per l in the cylinders being fed 120 mg CN^- per day (Cylinder No. 2) and 60 mg CN^- per day (Cylinder No. 3) respectively; however, mechanical failures make these data somewhat questionable except for an order of magnitude value. During the last 19 days of operation (days 166 to 185) when no mechanical failures occurred, the solids concentrations completely reversed and appeared to reach equilibriums at 150 mp per l and 220 mg per l in Cylinders No. 2 and No. 3.

A conclusive explanation for this shift in solids concentration cannot be given with the data available at this time; however, these data do indicate a different biological composition in the two systems which could account for the unusual results.

TABLE 5.—CARBON RECOVERY DATA

	Cylinder No. 1[a]		Cylinder No. 3[b]	
Day	Carbon recovered, mg	Carbon added, mg	Carbon recovered, mg	Carbon added, mg
1	55.5	51.4	23.3	25.1
2	59.3	49.2	20.2	25.1
3	52.3	51.4	32.6	25.1
4	48.2	51.4	22.0	24.0
5	50.0	51.4	23.7	25.1
6	39.0	49.2	24.0	24.0
7	50.8	51.4	24.0	25.1
8	47.8	49.2	23.4	22.9
9	49.2	51.4	25.0	25.1
10	49.0	47.0	25.5	25.1
11	42.4	51.4	24.2	24.0
12	48.8	49.2	21.6	25.1
13	49.0	51.4	—	—
Total	641.3	655.0	289.5	295.7
% Carbon Recovery	97.91		97.90	

[a] Feed = 117 mg CN^- per day

[b] Feed = 57 mg CN^- per day

The nitrogen recovery data (Tables 2 and 3) indicate that from the 131st to the 169th days considerable change occurred in the distribution of nitrogen in the supernatant of Cylinder No. 3 while little change occurred in Cylinder No. 2. This change in Cylinder No. 3 involved a decrease in percentage nitrites from 50.0 to 20.7 and an increase in the percentage nitrates from 35.3 to 76.4. During this same period in Cylinder No. 2 the percentage nitrites decreased only slightly from 70.0% to 67.0% and the percentage nitrates increased only slightly from 15.8% to 23.9%. This change in nitrogen distribution and the high percentage nitrates in the supernatant of Cylinder No. 3 indicates the growth, during this period, of a nitrifying organism such as nitrobacter, which is known to convert nitrites to nitrates and to have little effect upon other forms of nitrogen.[10] The additional growth of such an organism in Cylinder No. 3 could have provided the additional suspended solids. This organism could also

[10] Tanner, F. W., Bacteriology, 2nd Edition, 1933.

have been present in Cylinder No. 2, but its growth may have been inhibited either by the higher cyanide feed in this cylinder or the high concentration of nitrites that existed throughout the experiment, or by both, for the latter is known to be a bacterial inhibitor.[11]

Additional evidence of a different biological composition in the two systems is the higher percentage of nitrogen in the suspended solids of Cylinder No. 2 (Table 4).

Although no equilibrium weight of mixed-liquor suspended solids could be determined, the data do indicate that metabolism is an activated sludge system fed only potassium cyanide and nutrients is sufficient to maintain the system.

CONCLUSIONS

From the information gained in these studies it can be concluded that:

1. Potassium cyanide can be metabolized and 99+% of it removed from solution by an activated sludge culture using cyanide as the only source of carbon and nitrogen.
2. Suspended solids can be maintained in the above system without additional sewage feed.
3. The portion of cyanide-nitrogen converted to ammonia, nitrite, and nitrate was 75% in a 3-l cylinder fed 120 mg CN^- per day while that in a 3-l cylinder fed 60 mg CN^- per day was 90%.
4. In both of the above systems 97.9% of the feed cyanide-carbon was concerted to carbon dioxide.

SUMMARY

Cyanide wastes have been a major problem in industrial waste treatment for many years. Present treatment methods for these wastes are chemical processes and in most cases very expensive to operate and hazardous to the operating personnel. In recent years it has been shown that these wastes can be treated biologically on trickling filters in the absence of sewage.

It was, therefore, the purpose of this study to conduct basic research on the biological treatment of potassium cyanide by the activated sludge process in the absence of sewage. Since cyanide wastes also contain heavy metals and organic cyanides, this study was not expected to produce a treatment method in itself; however, it was expected to provide basic metabolism data for future investigators who will be determining the actual design criteria and the feasibility of such a process.

Two 3-l cylinders of cyanide acclimated activated sludge were fed concentrations of 60 mg and 120 mg CN^- per day (hourly increments) for a period of 185 days. One liter of settled supernatant was decanted daily and replaced with 1 l of nutritionally supplemented dilution water, buffered at pH 7.9. No solids were withdrawn from the systems during the 185 days except for analytical tests.

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[11] "Growth and Autotrophic Metabolism of Nitrosomonous Europaea," Journal of Bacteriology, Vol. 76, August, 1958, p. 217.

It was shown that potassium cyanide can be metabolized and 99+% of the cyanide removed from solution by an activated sludge culture utilizing potassium cyanide as the only source of carbon and nitrogen. Suspended solids growth in such a system was very slow, but was sufficient to maintain the system for an extended time. Seventy-five and 90% of the cyanide-nitrogen removed from solution was recovered as ammonia, nitrite, and nitrate in the supernatants of the cylinders being fed 120 and 60 mg per day CN^-, respectively. In these same cylinders 97.9% of the cyanide-carbon was converted to carbon dioxide.

ACKNOWLEDGMENT

This investigation was supported by a grant from the National Institutes of Health, Public Health Service, U. S. Department of Health, Education and Welfare, Washington D. C.

The authors also wish to thank Charles Forney, Jr., Instructor in Civil Engineering at The Pennsylvania State University, for his assistance in the preparation of the photographs and illustrations used in this report.

Journal of the
SANITARY ENGINEERING DIVISION
Proceedings of the American Society of Civil Engineers

ROLE OF PRICE IN THE ALLOCATION OF WATER RESOURCES[a]

by Lawrence G. Hines[1]

SYNOPSIS

This paper examines the price-cost function in the allocation and utilization of water resources in the United States and consists of analysis of (1) the market valuation process, (2) the factors affecting the determination of municipal water rates, and (3) the shifts of costs that result from different water uses.

INTRODUCTION

Water prices in the United States are a hybrid of economic and social forces. The unusual versatility of water as a low-cost economic good permits it to satisfy a great variety of private and collective wants, but also leads to special problems in pricing and allocation. These problems are related to (1) the frequent failure of direct water charges to cover total costs of production and distribution, (2) the modification or neutralization of market direction of water allocation through legal arrangements and existing customs, and (3) the inability of the private market process to identify and compensate for all costs that arise in the development and exploitation of water resources. This paper examines problems (1) and (3)—the consequences of the failure of direct water

Note.—Discussion open until June 1, 1960. Separate Discussions should be submitted for the individual papers in this symposium. To extend the closing date one month, a written request must be filed with the Executive Secretary, ASCE. This paper is part of the copyrighted Journal of the Sanitary Engineering Division, Proceedings of the American Society of Civil Engineers, Vol. 86, No. SA 1, January, 1960.

[a] This is a revision of a paper delivered at the Academy of Science meetings, Dallas, Tex., December 1957. The author is indebted to J. J. Flannery for suggestions in the preparation of this paper.

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charges to cover total costs and the nature of the transfer costs of water use.[2]

NATURE OF WATER RESOURCES AND THE VALUATION PROCESS

In both its physical and economical aspects, water is one of the most renewable of natural resources. Water can be reused, sometimes without artificial treatment, and it is replenished in the normal course of the hydrologic cycle. An average of 2.5 ft of water falls to the earth annually in the United States, with a run-off of approximately 1,200,000 mgd. National water supply averages are deceptive, however, in a country as large and diverse as the United States, because rainfall and storage facilities differ substantially from one region to another. Storage of water occurs in two physical forms: surface supply, which is the more important source of our water, and ground water deposits, which recently have become increasingly important.[3] Ignoring the possibility of "mining" ground water, the aggregate physical supply of water in the United States is the annual precipitation-runoff of 1,200,000 mgd. This figure does not represent the upper economic limit of our supply, however, since major portions of a given rainfall are repeatedly reused in the more populated areas before they are lost as runoff to the sea. Water scarcity is only locally—and generally temporarily—the result of physical shortage, and our water problems are largely due to maldistribution of existing supply and deterioration of water quality following industrial, municipal, and agricultural use. Because of water's transportability and amenability to quality improvement through treatment, the limiting factor in water shortage is invested capital quite as much as the physical supply of water.

The renewability of water increases the economic flexibility of its supply. Although water resembles other flow resources, such as air and sunlight, unlike such resources a given quantity of water can be held captive as well as reused.[4] A major exception to non-depletive water use occurs in farming.

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2 Extensive analyses (and debate) are available on the economic implications of water-rights doctrines. See, for example, "Some Economic Issues in Water Rights," by S. V. Ciriacy-Wantrup Journal of Farm Economics, Vol. 37, No. 5, December 1955, pp. 875-85; "The Law of Water Allocation in the Eastern United States" edited by D. Haber and S. W. Bergen, New York: Ronald Press, 1958; "The Case for Private Decision-Making in A System of Water Law," by J. W. Milliman, Santa Monica: Rand, September 1958; "Water Resource Law: Report Volume 3" by The President's Water Resources Policy Commission, Washington: Government Printing Office, 1950.

3 In 1955 surface Water sources supplied 194,000 mgd and ground water deposits contributed 46,000 mgd in the United States. "Estimated Use of Water in the United States," by K. A. MacKichan, Geological Survey Circular 398, U. S. Dept. of the Interior, Washington, D. C., 1957, p. 1.

4 The water supply is replenished by rainfall and renewed by natural streamflow or artificial treatment. Water treatment may take place before used water is reintroduced into a stream through interception by a pollution abatement system or before the water is reused through settlement, filtration, chlorination, and related processes. There are of course limits beyond which water cannot be restored to usefulness by either natural or artificial treatment. A build-up of dissolved solids may impair water usefulness over a wide range and some pollutants cannot be readily removed from water. For example, no practicable method of completely removing detergents from water has been developed, resulting in sudsing tap water for some communities that obtain their water supply from treated waste water.

Agricultural water use, which constitutes approximately half the demand for water in the United States, results in the loss of water to the plant and culture media with only slight possibility of recapture from runoff or transpiration.[5]

Water uses differ not only in the effect that a given use has upon the residual supply, but also in the nature of the control surrounding its allocation. In order of decreasing private market control, the major water demands in the United States arise from (1) municipal, (2) industrial, (3) agricultural, and (4) recreational uses. Industrial and agricultural water uses, frequently contrasted because water is an ingredient of these different kinds of production, are subject to different degrees of market and public control. Water for industrial purposes may be obtained from municipal sources under various price arrangements as well as self-supplied through capital investment, while to a lesser extent similar arrangements may at times take place in some of the specialized types of agriculture, such as truck and irrigated farming.

Increasing and sometimes competitive demand for water for different uses has led to the assignment of "values" for water in different uses, generally with little regard for the process of incremental or marginal analysis. The Paley Commission, for example, assesses the value of water in agricultural use as equal to approximately 10 cents for 1,000 gal., whereas manufacturing use is said to average $5.00 per 1,000 gal. used in 1952.[6] Such calculations are suspect on at least two counts: (1) they derive a water value in different uses primarily from the ratio of water inputs to the worth of the finished product, thus ignoring the contribution of other factors of production, and (2) they contrast the value productivity of a given water use for a particular water market area with different water uses in other market areas where the supply and alternative opportunities for employing water may be quite dissimilar.

A ratio of water input to value of the finished product (or to "value added" in the productive process) merely indicates whether water is used in an economic process that produces a high or low value. It does not justify an inference that all resources used in such processes derive higher value than those employed in producing less highly priced finished products. One might reasonably contend that the contribution (and value) of common labor in the steel industry is greater than similar labor in the packing-house industry because

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[5] A depletive water use, such as farming, makes a net reduction in the water supply, whereas a non-depletive use may impair the quality of the water but not appreciable affect the quantity of water available for reuse. Water supply data and literature usually identify a depletive use as consumptive and a non-depletive use as non-consumptive. Consumptive and non-consumptive are not satisfactory economic designations, however, since any water use (whether depletive or non-depletive) constitutes economic consumption. Professor Timmons has proposed a host of categories for the classification of water uses. He makes an initial separation between consumption and production uses, and a breakdown of the latter into existential non-exhaustive and potential non-exhaustive. "Theoretical Considerations of Water Allocation Among Competing Uses and Users," by J. S. Timmons, Journal of Farm Economics, Vol. 38, No. 5, December 1956, pp. 1245, 6. Timmons' basic distinction between production and consumption appears to be essentially arbitrary and may lead to confusion with the more familiar usage of consumptive water use.

[6] "Water for United States Industry," by J. R. Barnes, The President's Materials Policy Report, Washington: Government Printing Office, Vol. 5, 1952, p. 86. See also "Relative Economic Returns from Industrial and Agricultural Water Uses," by S. T. Powell, Journal of the American Water Works Association, Vol. 48, August 1956, p. 991.

the finished price of steel is higher than meat products. Any resource that can be varied independently of other factors in the productive process[7] will be added to the point where the increment of revenue from its use is equal to the added increment of cost, that is, where marginal cost equals marginal revenue. In carrying the use of a factor such as water to the margin where the value output from the discrete input is equal to its cost, different enterprises will not employ the same ratio of water inputs to finished product, but the value of water to any given enterprise within a continuous water supply area will be essentially the same. Adjustment of firm water demand to changes in the price of water presumes that the individual firm does not control the price of water, but much the same process takes place in the case of self-supplied water supply where the firm equates its water production and use with the cost (price) of production.

The aggregate effect of equating incremental factor cost with factor return by water users in a given market area establishes the supply price (value) of water. If the price of water rises, whether from decreased physical supply, increased demand, or both, water users will react to the price change differently depending upon the essentiality of water in the productive process and the worth of the product produced. Higher water price may thus be expected to curtail its use in certain industries, such as agriculture, where the quantity of water used is large and the price of the finished product low in comparison with competing demands. At any one point of time, however, the value of water in one productive process in the same market will be roughly equivalent to that of any other process. Only as the price of the factor is raised will there be imposed upon water users the necessity of a higher yield that will shift

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[7] The possibility of varying a given factor independently of other factors is a crucial requirement for value determination by marginal or incremental analysis. Independent variability of factor application necessitates some degree of physical divisibility of factors, which is well satisfied in the case of the water resources, and a technical process that is not characterized by large elements of fixed production coefficients. Since the nature of production coefficients varies for different industrial processes, generalization is hazardous, but the likelihood of flexibility in production coefficients is enhanced as the period of time available to the firm for modification of production arrangements is lengthened.

Inconclusive but significant evidence of the potential range of production coefficient flexibility in water use has been collected by Fortune magazine in a small statistical sample of representative firms in large water-using industries. The Fortune survey asked: "If water were to become, say, twice as expensive as it is today, (at one of your newer plants), presumably it would pay you to increase the amount of water re-used or recycled. Under such circumstances, by about what per cent could you reduce the plant's demand for fresh water?" The replies were tabulated as follows:

Industry	Percentage	
	Minimum	Maximum
Steam Power	0	95
Steel	0	40
Chemicals	10	60
Petroleum	0	12
Pulp & Paper	0	26

Source: Editors of Fortune, "The Mighty Force of Research" by the editors of Fortune, New York, McGraw-Hill, 1956, pp. 120-1.

water-resources from lower to higher productivity employments. Although a shift in resource allocation may in some cases result in the total elimination of some kinds of economic activity, for the most part water use curtailment will not be terminal or symmetrical for different firms and industries, restoring equilibrium where marginal returns in various uses are approximately equal to marginal costs.

As emphasized above, the evaluation and allocation process cannot be extended beyond the relevant market. Generalizations on the economic priority and value comparisons for broad categories of water uses for the economy as a whole are of limited validity. Aggregate data on water demand and supply are useful primarily as rough indicators of the extent of water exploitation in the economy, not as measures of the efficiency of resource allocation. The economic efficacy of a given water allocation arrangement can be determined only through an analysis of the limited range of opportunities for employing a given water supply. Higher productivity and greater yield from water use in one section of the country is not acceptable evidence of "inefficient" water use in another section of the nation where equivalent opportunities for use and similar supply conditions do not exist. Water has different values in different markets—and the market arrangement resembles that of non-competing labor groups. An abundant supply of common labor will not appreciably affect the productivity and wage return of highly trained technicians because little occupational movement occurs from one labor group to another. So in the case of distinctly different water markets: where mobility of resources is absent, the high demand and limited factor supply of one region cannot be transferred as a cause of "inefficient" resource use to areas where similar conditions do not prevail.

The foregoing analysis should not be misinterpreted to confer sanction upon the use of a factor in a lower-productivity capacity when its supply is insufficient to satisfy its demand by higher-productivity employment. Resource rationing to the point of exclusion of some uses occurs primarily as a result of increased factor marginal productivity (value). Institutional arrangements that impair the flow of resources from lower to higher productivity alternatives violate the strictly economic standard of resource allocation. Disregard of the economic standard is sanctioned at times to attain objectives other than economic efficiency. Water-rights law and the promotion of the "family farm" may illustrate instances where non-economic objectives are attained that excite greater approval among Congressmen and their constituents than among economists.

Inefficient allocation of the water resource occurs not only when a more productive alternative use is foregone, but also when the current development endangers a future water supply that will be employed at substantially greater yield than achieved by present exploitation.[8] Water deficiency may arise, as

[8] A later yield must exceed present return by an amount sufficient to compensate for the futurity of its occurence.

it has in some parts of the Southwest,[9] when ground water is extracted more rapidly than it is replenished by rainfall. Whether an overdraft of ground water is economically desirable or undesirable, however, cannot be answered by simple reference to the normal balance of the water table.[10] The critical question is whether the mined water is devoted to the most productive use within the opportunities available during the present and the discounted prospects of the future. Depletion of a given ground water supply is little different economically from the exploitation of an exhaustible mineral. The essential consideration is whether society can put the resource to a higher use, now or in the future, plus recognition that if the overdraft is continued indefinitely both the resource base and the economic activity created by the resource may be irreversibly impaired. In ground-water mining special problems may arise in areas where salt-water intrusion is likely to occur when the overdraft lowers the water table to below sea level. At times destruction of large amounts of water by intrusion pollution may take place under the stimulus of relatively small incremental gain. In such cases the social loss may be great in comparison with moderate private gain,[11] unfortunately establishing a pattern of

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[9] Regional water shortages and ineffectual control of pollution are evidence of either inadequate planning, insufficient investment, or both. As an example of regional water deficiency, Arizona—among the 17 western states that are using approximately 70% of the water supply that can be developed with economic feasibility—has reached beyond the dependable supply within its borders, and California, Texas, Louisiana, and Arizona are pumping heavily from ground water supplies. As a result, in regions such as the Texas High Plains the ground water withdrawal rate may be as high as thirty times the inflow and the overdraft for the Southwest as a whole is in the neighborhood of 5 bgd.

In spite of the fact that in 1953 many communities imposed some form of restriction in water use, the United States is not running out of water as many popular and semi-popular articles imply. The water "problem" in the United States is the result of one or a combination of the following factors: (1) regional shortage, (2) non-economic pricing of water, (3) ineffectual control of pollution (that is, insufficient capital investment) and unsolved technicalengineering problems.

[10] J. H. Snyder contends that "Economic forces . . . have stimulated groundwater mining—that is, annual draft rates on ground water beyond the safe yield level—creating overdraft and decline in ground-water levels. The ground-water flow resource or recharge volume of a ground-water basin, expressed as an annual average, is equivalent to the physically determined safe yield of that basin. It represents the amount of water that may be withdrawn from ground-water storage indefinitely for man's use without significantly affecting the character or volume of the reservoir.

Safe yield draft rates, merely to preserve the physical character of the resource, do not automatically become a policy goal of ground-water utilization programs."—"On the Economics of Ground-Water Mining—A Case Study in an Arid Area," by J. H. Snyder Journal of Farm Economics, Vol. 36, No. 4, November 1954, p. 600.

[11] The extent of private gain from ground-water mining will vary for different regions and different times. No generalization is possible, but an illustration of the magnitude of private gain from overdraft is found in a study of the Antelope Valley, California, region. "In dollars and cents terms, Valley farmers have profited from ground-water mining. For example, using the ground-water stock at a safe yield rate (draft-recharge) and devoting the entire amount to alfalfa production, it is estimated that operators' earnings from alfalfa for the period 1927-1950 would have totaled less than $5,000,000. Actually, for only the period 1947-1950, alfalfa operators' earnings alone totaled $4,500,000. Thus income generated by mining the ground-water stock resources may easily exceed a perpetuity income resulting from maintaining balance between recharge and draft."—Ibid., pp. 609-10.

commercial exploitation that cannot easily be reversed. The physical nature of ground-water deposits, which permits private owners to compete for a larger share of a given water supply, frequently encourages an antisocial rate of withdrawal.[12] Public control of the rate and method of water extraction, similar to that imposed in some oil regions facing much the same problem, may at times be necessary to bring private exploitation practices in line with social objectives.

The optimum social rate of exploitation of ground water requires the distribution of supply between present and future so as to maximize the return to society over both periods. This rule may be generally applied to natural resource development whether the exploitation involves "mining" or not. The determination of the rate of present resource exploitation, which is dependent upon the discounted returns from future use, also establishes the appropriate rate of conservation. The frequent identification of conservation as "wise use" of resources requires amplification to give it meaning, just as does the economist's short-hand expression of "efficient" or "optimum" allocation of resources. It is apparent, however, that the conservation problem is an extension of the economic problem. Both emerge because of scarcity, but to the extent that they can be separated the economic problem must take priority because no choice between present and future arises if materials, manpower, and capital are unlimited.[13]

Pressure of scarcity compels society and individuals to choose what to produce in the present as well as what to withhold for the future, and allocation of resources achieving a socially satisfactory distribution between the present and future is attained only when the market mechanism accurately reflects the relative values of resources. A price that does not correctly measure the scarcity of a resource distorts the use of the resource in relation to other factors. Analysis of socially inappropriate pricing, generally limited to non-competitive situations, seldom considers the problem of rationing commodities or resources in other than the present. It follows, however, that a price that is non-competitively high restricts the use of resources and the supply of commodities in the present, thus making available a larger supply of an exhaustible resource for the future. A price that is "too low" shifts part of the cost of product production to other factors or institutional sources of revenue and draws more heavily upon the fixed resource stock than would otherwise be the case.

In instances of resource underpricing, the use of a resource may be pushed to the physical limit of supply without satisfying effective demand. The failure of price to rise as the resource becomes more scarce and as physical depletion rates increase impairs the rationing function of the pricing system,

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[12] "Commonality, the Price System, and Use of Water Supplies," by J. W. Milliman, Southern Economic Journal, Vol. 22, No. 4, April 1956, p. 429. Professor Milliman treats the consequences of competitive withdrawal of ground water as a "spill-over" cost.

[13] In the formal sense, the conservation problem involves a special application of capital theory, although there may be important instances in which the market does not satisfactorily "solve" the conservation problem just as there are times when it fails in the solution of the economic problem.

which generally winnows low-value resource uses from the market and apportions supply among higher-value uses. Sluggish response of price to increasing scarcity disorganizes the operation of the market, resulting in: (1) uneconomic employment of factors, (2) the need for administrative direction or resource allocation, and (3) a bias in favor of present (versus future) resource use.

Although the market cannot be expected to accommodate all social goals, automatically establishing prices that are simultaneously private incentives and social objectives, the market does promote conservation when private and social goals coincide. The market is likely to underrate the need for conservation in cases where (1) market prices reflect individual choices that do not coincide with social objectives,[14] (2) institutional arrangements inhibit the ideal operation of the system and (3) knowledge of society's future needs is less complete and accurate than information of present requirements. (Point 3 may also lead to a rate of conservation that is at times too high.)

MUNICIPAL WATER PRICING

Water pricing in the United States, while differing among communities and uses, generally reflects some element of subsidy to the consumer. Although there is obvious need to promote certain social and sanitary uses of water through low price,[15] it is the thesis of this paper that the higher volume of water use in the present and future would closer approximate the social optimum allocation if more emphasis were placed on orthodox principles of pricing. Along with an increase in the market price for most water uses,[16] extra-market cost transfers should be assessed and imposed upon those responsible for depletion and degradation of the water resource.

In 1953, 1,072 communities in the United States experienced some degree of water shortage, generally resulting in various administrative restrictions upon water use, but infrequently leading to significant price adjustment.[17] The

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[14] It should be re-emphasized, however, that producer's private interest in non-competitive price may lead to distribution of resource use in favor of the future. For other considerations, "Economics and the Public Interest," by L. G. Hines, Land Economics, Vol. 31, No. 2, May 1955, p. 108.

[15] See Note 18, below.

[16] Data on the costs of water production are meager. "The 15,400 waterworks . . . do not report their operations to any single agency. This is unfortunate. The Federal Power Commission collects from all electric and gas utilities, both publicly and privately owned, a large amount of statistical data permitting comparisons of the rates and relative operating efficiencies of these essentially noncompetitive utilities . . . . It is essential that all water works utilities, both publicly and privately owned, be required to report, on a uniform accounting and statistical basis, all fundamental and statistical data which can be compiled in one office and made available to all waterworks managements and to other interested agencies and persons." "A Water Policy for the American People: The Report of the President's Water Resources Policy Commission," Washington: Government Printing Office, Vol. 1, 1950, pp. 180-1.

[17] Water shortages in New York City have resulted in review of this community's problem more thoroughly than most, but careful investigation of the role of price upon water consumption appears to have been neglected. A study by the Mayor's Committee on Management Survey of the City of New York, "Future Water Sources of the City of New York: Report of the Engineering Panel on Water Supply," New York, July 1951,

market approach to this problem would be a rationed reduction in water use through price increase, curtailing consumption to the point where no economic shortage existed. Clearly the market solution may be socially inappropriate in some cases, but in failing to price water according to its scarcity, cumbersome administrative restrictions that generally require active consumer cooperation for success must be imposed to prevent over-depletion of existing water supplies. In view of the special circumstances surrounding the fixing of water rates by most communities, more attention might profitably be given to the consideration of the economic aspects of water pricing.

Municipal water rates are the most unscientifically determined price in the public utility field.[18] Rate determination in the water industry is complicated by such factors as: (1) the dual function of fire protection and supply of water that most systems perform, (2) the political influences that at times take ascendency over economic considerations, and (3) the feeling held by many that water should be priced nominally.[19] Even though water charges generally represent a small proportion of the consumer's total budgetary outlays, there is evidence that changes in water rates result in modification of the amount purchased. This is particularly apparent when consumption is made a function of price, as in the case where a fixed annual charge is replaced by metered rates. The use of metered rates has reduced water consumption by as much as 50% and meter installation has sometimes been recommended as a means of avoiding the necessity of expanding water installation capacity.[20]

The opportunity to disregard market pricing practices is afforded by the high proportion of publicly owned and operated water systems in the United States. Slightly less than twenty per cent of the water systems in the United States are privately owned and controlled, and public ownership in this field greatly exceeds that in other utility industries. Although generalization in the water utility field is risky because of meager information and the diversity of service arrangements, one of the important reasons for the predominance of

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totally ignores this aspect of the problem except to the extent that metered rates may be expected to curtail consumption. The report is concerned almost exclusively with the physical supply of water in terms of how it can be augmented from additional sources and how loss can be decreased by improving main maintenance and correcting faulty plumbing.

[18] "Public and Private Ownership of Water Supply Utilities," by R. B. Eutsler, The Annals, Vol. 201, January 1939, p. 94.

[19] "Municipal Finance," by A. E. Buck, New York: Macmillan, 1926, p. 516 et seq. The major justification for nominal water charges is to encourage its use for sanitary purposes. This objective may be achieved, however, and at the same time permit price to ration water for less essential uses. Instead of the decreasing unit charge with increased consumption (or a flat rate), typical of many water rate structures, a low initial charge for an estimate of the amount of water necessary for household sanitary requirements might be imposed, followed by a progressively increasing charge to curtail non-sanitary water uses.

[20] "Economics and Public Utilities," by E. W. Clemens, New York, Appleton-Centry-Crofts, 1950, p. 124.
Eutsler cities studies in Ohio indicating that meters may be expected to reduce the average daily consumption of water from 170 to 90 gal. in villages and from 170 to 100 gal. in cities.—op. cit., p. 93. It should be noted, however, that the initial reduction in water consumption following a price increase or metering of water may not persist in full force indefinitely.

public ownership appears to be inadequate return on private capital investment—a further indication that water is underpriced. In reviewing the historical trend toward public ownership in the water industry, Eutsler says[21]

> Privately owned water works . . . encountered difficulties in charging rates sufficiently high to cover the costs of supplying water. Private capital therefore tended to seek more profitable fields of investment, and left this field undeveloped. If water were to be supplied, it was up to the municipality to do it. Moreover, municipalities sometimes found it possible to shift some of the costs of construction to property owners by assessment, and some of the current costs of operation, especially interest on bonded indebtedness, to the taxpayers in the form of taxes.

Further evidence that publicly-owned water utilities have not generally followed orthodox market practices in pricing water is revealed in an exhaustive study of water works statistics by H. F. Seidel and E. R. Baumann.[22] Although Seidel and Baumann did not undertake the analysis of the statistical data periodically collected by the American Water Works Association as an investigation of the pricing policies of water utilities, the study of various aspects of private and public water companies reveals important differences in pricing policy, rate of return, and other economic features. On the whole, private water utilities have charged higher water rates and adjusted more quickly to

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[21] Op. cit., p. 91. Clemens concurs that one of the factors responsible for the disproportionate public ownership of water systems is "The business is so frequently unprofitable that it is unattractive to private capital."—op. cit., p. 124. Troxel contends "Private investors apparently are not so anxious to invest in water systems as in electric, gas, and telephone plants. A private water company has the customary responsibilities of a utility firm, and in addition it is obligated to provide plant capacity for an expanding population. A water company can be confronted with increasing costs of operation as it expands . . . If the unit costs of an expanding system are increasing, the private company wants higher and higher water prices as it expands. But while a city government wants more water, it also may try to prevent increases in water prices, ignoring the connection between higher prices and additional investments in the water plant. "Economics of Public Utilities" by Emery Troxel, New York: Rinehard, 1947, p. 651.

Bello states that "For the last 100 years private utilities have been getting out of the water business, primarily, it appears because the ratio of capital investment to sales is unattractive!" "How are We Fixed for Water?" by Francis Bello, Fortune, Vol. 49, No. 2, March 1954, italics added, p. 125. Although water utilities have an abnormally high ratio of capital investment to operating revenue—approximately 10 to 1 as compared with other public utility ratios of 5 to 1 and ordinary manufacturing of roughly 10 to 7—the relationship of capital to revenue is of no significance in encouraging or dissuading investment in a given field. In instances of low capital turnover, as in the case of water utilities where sales are small compared with capital investment, a larger proportion of sales revenue must be earmarked for capital amortization, but the rate of return on capital must be equivalent to other opportunities for investment, consistent with the risks and uncertainties of the enterprise, in order for capital to be attracted to and retained by the firm.

[22] "A Statistical Analysis of Water Works Data for 1955," by H. F. Seidel and E. R. Baumann, Journal of the American Water Works Association, Vol. 49, No. 12, December 1957, pp. 1531-66. The statistical data cited in this section have been obtained from the above source, but not the interpretation of these data.

rising prices than publicly-owned water utilities. Analysis of the 1955 data indicates that the monthly charge per 1,000 cu. ft. of water differs in the order of $2.62 for public utilities and $3.70 for private utilities.[23] Direct charges for water service in general have been lower for public utilities, with private utilities allowing on the average 10% less water on a minimum bill while maintaining 33% higher charges; private utility fire service rates were one-third higher.[24] Seidel and Baumann conclude that ". . . since 1950, publicly owned utility earnings have been keeping up with cost trends, while privately owned utilities have been doing mildly better. Both have still to make up the considerable ground lost during 1945-50. If the relationship between costs and earnings in 1945 was satisfactory (and there is no reason to believe it was better than that) further rate increases appear mandatory."[25]

Although aggregate investment and revenue data for the water industry may conceal case differences of significance, an analysis of 1956 data for publicly-owned water utilities indicates that an increase in revenue of $1.714 billion would be necessary to break-even for that year. This would require an increase of 47.5% in gross operating revenue to achieve an annual return of 4.17% of the investment (replacement) value of publicly-owned water utilities in the United States.[26]

TRANSFER COSTS IN WATER USE

The supply of water, which is to say the cost of water, is a function of quality quite as much as quantity. Because of the unique renewability of the water resource, which generally permits the same water to be reused, the cost of water to a given user (or community) is determined partly by the pollution load carried by the water from other population centers. When the water supply source is a flowing stream, the use of this watercourse as a low-cost means of waste disposal forces the resource to serve dual and antagonistic purposes. Since it is usually possible for a community or industrial water user to separate the withdrawal of stream water from the area of waste disposal, any one community may minimize its costs by untreated stream disposal of wastes. This separation permits a varying portion of such costs to be shifted to other (downstream) communities. Because most communities are "downstream" to other communities, however, whether a given community gains or loses from following a policy of treating its water and not treating its waste depends upon how large and how far away is the upstream community, the nature of the

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[23] Ibid., p. 1533.

[24] Ibid., p. 1547 and Table 22, p. 1563.

[25] Ibid., p. 1566. "Earnings," as used by Seidel and Baumann, is apparently equivalent to the economist's "gross revenue," not the net concept of the public utility analyst.

[26] "Financial Requirements of Water Utilities" by W. L. Picton, New York: American Water Works Association, Inc., October 1958, pp. 8-9. I am greatly indebted to Mr. Walter L. Picton, Director of the Water and Sewerage Industry and Utilities Division of the U. S. Department of Commerce, Washington, D. C., for extremely helpful information and discussion on water utility investment problems.

wastes, the flow variations of the stream, and a variety of similar considerations.[27]

To answer the question of whether society gains or loses from using watercourses alternately as sources of water and for disposal of untreated wastes requires a comprehensive survey of the economic gain and loss to all parties. As a theoretical starting point, the prohibition of any pollution may be taken to represent the condition under which no transfer of cost would take place. But although enforcement of a "no pollution" ban has become increasingly appropriate as a tenet of public policy, the application of such restriction ideally should be determined by the particular conditions that obtain in specific watercourses. After allowance for the generally increasing demand for water as a result of population growth and industrial development, which establishes a strong presumption in favor of more rather than less investment in pollution abatement facilities, prevailing conditions in certain areas may justify elimination of pollution in order to maximize society's welfare. This condition differs from that typical of the early development of our economy when industries and communities did not contribute substantially to the pollution load of watercourses and when the increased industrial output or community convenience outweighed the economic loss and social distress caused by pollution. The location of community and industrial installations in an area essentially isolated from other population concentrations may still satisfy these conditions. But it is obvious that such situations are of decreasing likelihood.

Economic loss resulting from pollution may be classified in two categories: (1) that resulting from community action which may affect other communities and private individuals and enterprises and (2) pollution by individuals and enterprises which may affect communities and other individuals and enterprises. These two types of cost-shifting may be distinguished on the basis of whether the transfer takes place, as in (1), from one portion of the public to another or, as in (2), where the shift is between individuals or from the individual to the public. The former transfer (1) is generally identified as a "spill-over" cost, whereas the latter (2) is more specifically defined as a "social" cost.[28] The following situations are suggestive of the possible cost transfers that may take place.

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[27] If the upstream community is small and distant, some kinds of waterborne wastes may be oxidized before reaching the source of the water for the downstream community. If the intervening surface waters are not significantly affected or intensively used, no appreciable cost shift will take place in this hypothetical situation. Unfortunately, such a situation becomes increasingly hypothetical with growth in population. Basic data on the extent and nature of water pollution in the United States are somewhat incomplete. The most frequently quoted publication is "Water Pollution in the United States," Washington, D. C., U. S. Public Health Service Publication No. 64, 1951.

See also, The Water Pollution Control Program of the U. S. Public Health Service, 1957-1958, Washington: Department of Health, Education, and Welfare, 1958, and Inventory of Municipal and Industrial Waste Facilities in the United States, Washington, D. C., U. S. Public Health Service Publication No. 622, 1959.

[28] Kapp defines "social" costs as including ". . . all direct and indirect losses suffered by third persons or the general public as a result of private economic activities." "The Social Costs Private Enterprise," by K. W. Kapp, Cambridge: Harvard University Press, 1950, p. 13.

The distinction between "spill-over" and "social" costs is useful for purposes of determining remedial action.

(a) Pollution of a community water supply by an industrial firm.—Social cost imposed upon the community.
(b) Pollution of one community's water supply by an upstream community.—Spill-over cost transferred to downstream community.
(c) Pollution by a community of a portion of the adjacent watercourse (presumably below the community's water supply intake) impairing the utility of the water resource for some members of the same community.—Spill-over cost from community to some of its constituents.

In assessing the nature and magnitude of such cost transfers, a monetary equivalent of the value of the water use impaired or destroyed by pollution represents the ultimate goal of economic analysis. Unfortunately, automatic measurement of the value loss to individuals and society in monetary units is complicated for numerous water-using activities because they do not involve transactions carried out within the purview of the market. At the same time, quality standards for different water uses vary widely—resulting in equivalent variation in the magnitude of the loss from cost transfer in cases of different uses. The cost of water production for human consumption, for example, increases in rough proportion to the degradation of the water quality. Assuming that for some human needs and certain industrial processes there is no satisfactory substitute for water, the price of this resource would be established at whatever height was necessary to cover its cost of production. From the development of the valuation process in the first section of this paper, however, it is apparent that the nature of water supply is not sufficiently limited to result in establishing water value exclusively on the basis of such priority needs. The total demand for water is made up of many other uses for which there are somewhat less than completely satisfactory technical substitutes, although such substitutes may not be less attractive economically. The substitute for loss of water uses from pollution is an investment in pollution abatement installations, thus imposing the cost for water degradation upon the agency responsible. As population increases and industry expands, the benefits impaired and destroyed by pollution of water increases and the loss from pollution to individuals and society increases. These changing values must be measured and the costs assessed in order to prevent inequitable transfers of burdens within society and to insure optimum allocation of water resources in our economy.

CONCLUSIONS

A primary function of the private market—the apportionment of resource supply to different uses—is not accomplished satisfactorily in the allocation of water resources in the United States. The significance of pricing water below cost has been discussed in Part II above, but the attainment of a socially optimum allocation of water resources may also be inhibited by the operation of

certain water rights doctrines[29] and the inability of the private market to encompass the full range of cost transfers that take place in the economy. In important instances, the market is not capable of measuring and relating to other water-using activities certain essential needs, such as those of health, sanitary, and recreational water use.

It is concluded that a closer approximation of the socially optimum allocation of water resources requires the following considerations:

(1) A low water price for that portion of personal consumption essential for health and sanitary purposes. (A subsidy will be required for this purpose.)

(2) A water price for other uses that covers the full costs of production, except in cases where specific public policy objectives are to be served.

(3) The elimination of water pollution in cases where:

(a) A health hazard is involved,

(b) Although pollution is the result of a public agency, the gain to society from abatement is greater than the cost of abatement,

(c) Abatement eliminates inequitable and substantial cost transfers between communities that otherwise cannot be satisfactorily adjusted,

(d) The individual or enterprise shifts to society or important segments of the public the costs of waste disposal through the impairment of public or private welfare, and

(e) Gross inequities result from private shift of costs of water disposal of wastes that benefit through low price the users of certain products, but injure through impairment of water resources other private parties.

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[29] See J. F. Timmons, op. cit., p. 1256, and "Discussion: Can Water Be Allocated by Competitive Prices?" by R. Barlowe, Journal of Farm Economics, Vol. 38, No. 4, December 1956, p. 1279. Barlowe contends that "In our appropriation doctrine states, and even in our riparian doctrine states, one's supply of water is much more dependent upon his possession of a water use right than upon his ability to bid up water prices. A person or industry with great need for water can often buy the land and water rights of others. But even so, it may be observed that the holders of water rights often use their water resources in a lavish or even wasteful manner at times when these same resources could be put to more productive use by other operators or other enterprises." —Ibid., p. 1280. In cases where water rights holders use water wastefully in comparison with alternative opportunities, the resource owner is acting irrationally or capriciously, does not have adequate information, or is confronted with indivisibilities in the transfer of water rights.

Journal of the

SANITARY ENGINEERING DIVISION

Proceedings of the American Society of Civil Engineers

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Note.—This paper is a part of the copyrighted Journal of the Sanitary Engineering Division, Proceedings of the American Society of Civil Engineers, Vol. 86, SA 1, January, 1960.

TREATMENT OF LIQUID RADIOACTIVE WASTES[a]

Closure by Conrad P. Straub

CONRAD P. STRAUB,[1] M. ASCE.—The author appreciates the comments submitted by P. Dejonghe of Belgium, Pierre Cohen of France, R. H. Burns of England, and L. Carlbom of Sweden, relative to this paper, which outlined European practice during 1957.

Mr. Dejonghe has brought up to date the manner of operating the facilities at Mol; and has added considerable information on the efficiencies of the waste treatment processes for the removal of alpha, beta-gamma, and strontium activity from some intermediate level wastes by a combination of chemical treatment and lignite column filtration.

Mr. Cohen has corrected some of the values initially reported and has indicated that the treatment at Saclay may be less expensive than that utilized by the British, and provides some additional information on the removal of specific radionuclides. In this connection, I should like to point out that a typographical error shows cesium as having a mass of 139 instead of 137.

Mr. Burns has pointed out the changes in British practice and has corrected some of the confusion which appeared in the author's write-up. He has provided much more recent information on the efficiency of the treatment processes utilized and indicates essentially that the vermiculite filtration columns were quite effective for the removal of cesium in the residual wastes.

Mr. Carlbom has indicated that there has been a change in the various categories of waste due to a revision in the initial estimates. His statements point to the difficulty of estimating the nature of the waste and the activity levels that one can expect beforehand. Detailed information on waste composition cannot be obtained until the wastes are actually produced.

The author appreciates very much the comments that were submitted by the European scientists and the time that they have taken to bring to date and correct the data obtained some years ago during a visit to the various laboratories concerned. Such exchange of information is exceedingly helpful in orienting others into the types of problems which one may encounter in the atomic energy field. It must be remembered, however, that all of the procedures described herein relate to low-level and intermediate-level wastes and have no bearing on the treatment of high-level wastes. These are stored in suitable receptacles at all sites at the present time.

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[a] January, 1959, by Conrad P. Straub.

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TRACTIVE RESISTANCE OF COHESIVE CHANNELS[a]

Discussion by Frank D. Masch

FRANK D. MASCH,[1] A. M. ASCE.—The author has presented a very interesting approach to the evaluation of the tractive resistance of cohesive sediments. Investigations of a general nature are always valuable when one considers that most published literature on this problem describes tests that have been performed to verify specific cohesive bed models.

Tests have recently been run at the University of Texas to study the erosion process in cohesive sediments. In these tests, scour was obtained by subjecting the horizontal surface of a cohesive sediment sample to the action of a submerged vertical jet. Although these tests were primarily directed toward the effect of the hydraulic characteristics on the rate of scour, several aspects were similar to those performed by the author.

In these tests, the depth and rate of scour in a given cohesive material were determined as a function of the nozzle velocity and the geometry of the jet. Tests were run on both remolded and essentially undisturbed samples. In all cases it was noted that scour began at points a short distance away from the center of the sample. This effect was reproducible as an initial condition and was independent of the jet velocity and elevation and the nature of the sediment tested. Since it was found that the depth of scour was a function of the logarithm of time, the scour rate was indexed by the ratio of the depth of scour to the log of time. This scour rate index was then found to be a function of the jet velocity, diameter, and elevation. It was also found that when under the influence of fixed jet geometry, a given sediment required a certain minimum jet velocity before any noticeable scour began. The variables influencing the scour rate index were combined into a Reynolds number. The Reynolds number describing the initial conditions was defined as the point of incipient scour. A given sediment was found to have a fixed point of incipient scour irrespective of the jet geometry. Beyond this minimum Reynolds number, however, the influence of nozzle velocity and jet geometry were evident.

It may be well to point out the effect of the nozzle elevation on the scour in cohesive materials. Although changes in nozzle elevation have no apparent effect on the location of the initial scour, elevation changes do effect the nature of the erosion after a very short period of time. The effect of nozzle elevation is explainable in terms of the geometry of the submerged jet. If the nozzle is very close to the sample, the potential core of the jet impinges on the surface of the sample and causes a very localized scour. Under these conditions it was found that a relatively deep narrow scour hole was formed in a very short time. The erosion under these circumstances is not truly representative as

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[a] June 1959, by Irving S. Dunn.

[1] Assoc. Div. of Hydr. & Engrg., Univ. of California, Berkeley, Calif.

the energy of the jet is dissipated by turbulence in a deep scour hole rather than by causing scour of the surface of the sediment sample. This occurrence was characterized by the relative jet elevation, defined as the ratio of jet elevation to nozzle diameter, of less than 6.5. On the other hand, for $h/D > 10.0$ the potential core of the jet does not strike the sediment surface and the jet energy is dissipated through shear in causing a wide area to be eroded. It was concluded that in tests utilizing a submerged jet, the ratio of jet elevation to nozzle diameter should be equal to at least 10.0.

These tests at the University of Texas have just recently been completed. The results will probably be submitted for publication at a later date.

ABSORPTION OF OXYGEN FROM AIR BUBBLES IN WATER[a]

Discussions by Shuichi Aiba and James J. McKeown and Daniel A. Okun

SHUICHI AIBA.[1]—This paper is a valuable contribution to the design and operation of aeration devices. It should be pointed out that the relationships between the liquid film coefficient K_L (especially, the overall coefficient K_La) and pertinent process variables at liquid submergence depths up to 15 ft. are developed.

The comments on this paper are as follows:

1. In Fig. 2, d_b and D_L are assumed constant, taking the fact of N_{Re} = const. into account. Then

$$\frac{K_L d_b}{D_L} h = \alpha \frac{K_L d_b}{D_L} A$$

where α = proportionality constant
A = interfacial area of transfer

The relation between $\frac{K_L d_b}{D_L} h$ and h is shown in Fig. 13 (re-plotted from Fig. 2). A straight line is drawn through the data points. The scattering of data points might be partly attributable to the complexity of bubbling liquid surfaces.

It is assumed that the intersection of the line with the ordinate represents the effects of bubbling surfaces and bubble formations at orifices on the oxygen transfer. Then, it is apparent from Fig. 13 that these effects become predominant as the submergence depth decreases. It is further considered that both of the slope and the intersection of this line depend on the geometry of aeration devices and on the operating conditions, in particular.

Fig. 14 is obtained from Fig. 13 through a procedure of

$$\frac{K_L d_b}{D_L} h - \left(\frac{K_L d_b}{D_L} h\right)_{h=0} = \frac{K_{L(b)} d_b}{D_L}$$

Since d_b and D_L are assumed constant, Fig. 14 indicates only that $K_{L(b)}$ is rather independent of h.

2. The correlation of Fig. 3 covers a range of bubble diameters of 0.05 - 0.2 cm. When it is assumed that v_b approximately corresponds to a range of 6-30 cm/sec (single bubble) or 6-10 cm/sec (chain-like bubbles),[2] a range of Reynolds numbers of 30-600 (30-200) is covered without changing the viscosity of water.

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[a] July, 1959, by W. W. Eckenfelder, Jr.

[1] Assoc. Prof., Biochemical Engr. Lab., Inst. of Applied Microbiology, Univ. of Tokyo, Japan.

[2] D. W. van Krevelen et al. Chem. Eng. Progress 46, 32 (1950).

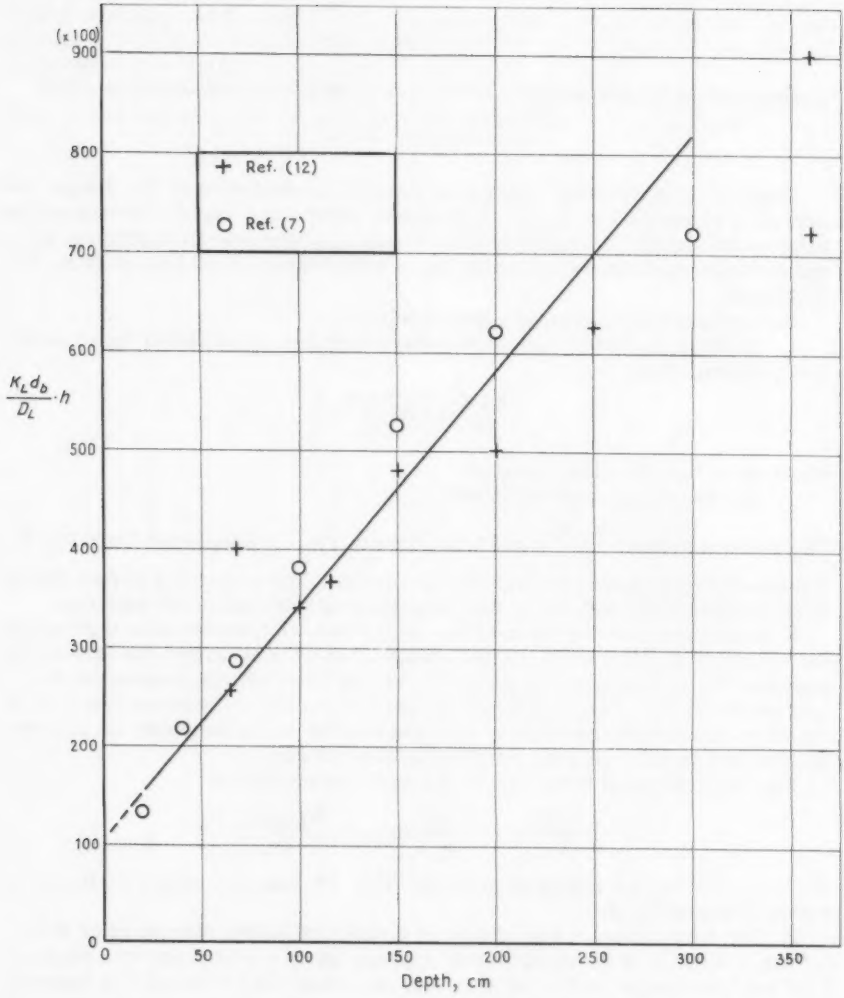

FIG. 13.—EFFECT OF SUBMERGENCE DEPTH ON $\frac{K_L d_b}{D_L} . h$

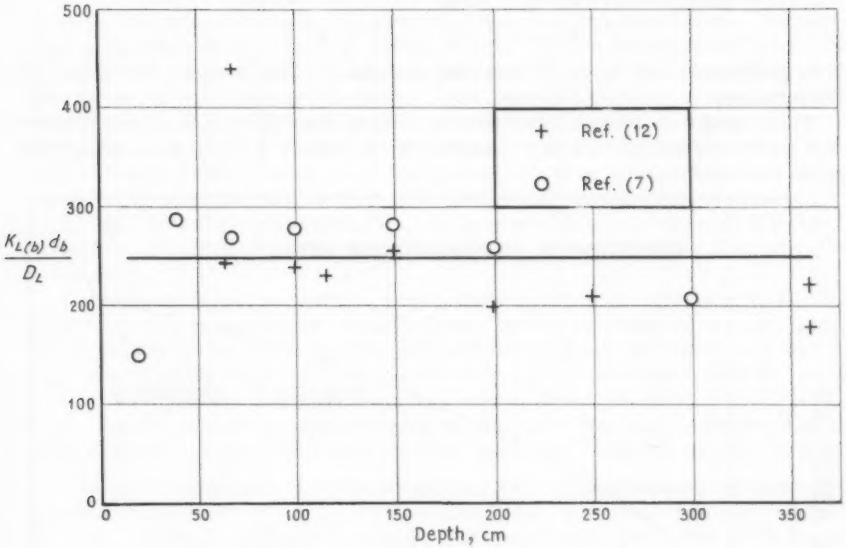

FIG. 14.—EFFECT OF SUBMERGENCE DEPTH ON $K_{L(b)}$

JAMES J. McKEOWN,[1] A. M. ASCE and DANIEL A. OKUN,[2] F. ASCE.—An empirical solution has been presented by the author for the evaluation of the oxygen transfer capabilities of specific diffusers. The procedure makes use of unitless quantities defined as Reynolds Number, Sherwood Number, and Schmidt Number in addition to tank liquid depth to define an aerator's capacity.

Eq. (3) sets forth three phases through which oxygen transfer takes place and consolidates them into a specific oxygen transfer coefficient for the complete system.

Bubble motion and shape characteristics are presented for three Reynolds Number ranges and the data of Pasveer are used to substantiate the relationship expressed in Eq. (4) for high gas rates.

$$d_b \propto G_s^n$$

Fig. 1 shows $K_L\, d_b/D_L$ as a function of $d_b v_b/\nu$ for various liquid depths. A cross plot of this figure shows depth varying with $K_L\, d_b/D_L$ to the -1/3 power. Fig. 3 then shows a replot of Fig. 1 including the depth function. Eq. (12) describes this relationship as:

$$K_L\, a = \frac{C\, h^{2/3}\, G_s}{V\, d_b\, S_c^{1/2}}$$

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[2] Prof., Dept. of San. Engrg., Sch. of Pub. Health, Univ. of North Carolina, Chapel Hill, N. C.

Eq. (4) is then substituted to yield Eq. (13) which states:

$$K_L a \cdot V = C'' G_s^{(1-n)} h^{2/3}$$

It is pointed out that the depth exponent is dependent on the type of diffuser and its location.

It is noted that the gas flow exponent ranges from 0.86-1.35. When greater than unity it suggests that the exponent "n" is negative, which does not appear to be reasonable.

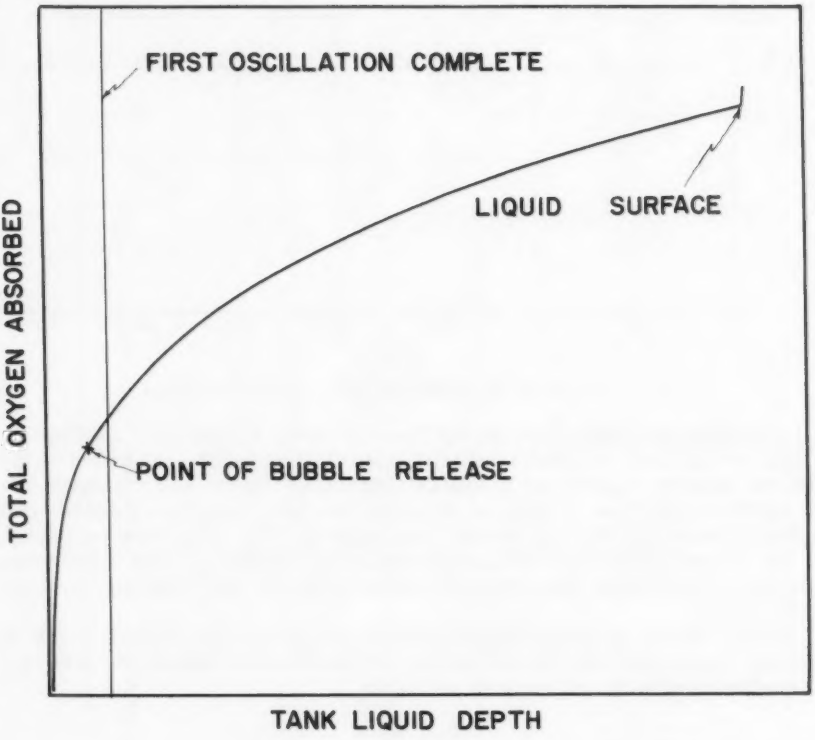

FIG. 1.—SCHEMATIC REPRESENTATION OF OXYGEN TRANSFER FROM AN AIR BUBBLE AS IT IS DIFFUSED IN A COLUMN OF WATER

Fig. 4 then produces the relationship for a diffused aeration device of:

$$K_L a \cdot V = C G_s^{1.35} h^{0.78}$$

In discussing this article several points need to be considered. They are summarized as follows:

1. The quantity d_b, which symbolizes the bubble diameter, needs clarification. Is it the diameter of the equivalent volume sphere or the average magnitude of the major axis of the ellipsoidal bubble? What assumptions are made with regard to bubble shape, and is it reasonable to assume the shape to be static throughout the travel of the bubble?

2. The data of Pasveer (7) indicate the gas flow per orifice to be in the low-intermediate range, whereas the author assumes a high flow range. Further, even if the diameter of the equivalent volume sphere is calculated from the $(A/V)_b$ given for each diffuser at each gas flow, there is little correlation between gas flow and bubble diameter. The diameter in fact varies very little with increasing gas flow and for diffuser G_1 the diameter remains constant. Therefore, the number of bubbles produced per unit time must increase with increasing gas flow. The frequency parameter then becomes a controlling factor along with the volume increase. The author ignores frequency.

3. The linearity assumed in Fig. 1 is questionable particularly at the greater depths. A partial explanation for this may be in the definition of d_b as noted previously.

4. The possibility of the gas flow exponent being greater than unity thus limits Eq. (13) to particular diffuser types. Bubble splitting is no doubt a factor in modifying the final equation and may not only be associated with nozzle type spargers but with certain liquids of low surface tension (that is, those liquids having concentrations of surface active agents present).

5. Eq. (13) refers to only one zone of gas flow. Eq. (12), however, may be expanded to fit those zones which occur at lower gas flows per diffuser orifice.

The problem of evaluating all the parameters influencing oxygen transfer on a commercial scale is a complex one. The kinetics of mass transfer need not be reviewed here since they have been quite adequately presented in the paper under discussion. One point which should be made at this time, is that the gaseous-liquid boundary separating the bubble from the solution is not rigid. The surface through which the gas molecules must pass is compressible. It may be thought of as elastic, deforming in order to equalize internal as well as external forces.

In porous diffusers a single bubble is formed by many pores. Each pore is of different diameter and length than its neighbor. Thus, depending on size and frictional losses, a few pores contribute most of the bubble volume. Prior to the bubble's release from its battery of orifices, its surface is being constantly renewed with entering gas. The volume of the bubble as it breaks from the forming device is a function of the bouyant properties of the gas in the liquid, the surface tension between both solid and liquid boundaries, the shearing forces developed within the liquid by its dynamic state, the diameters of the pores concerned, the liquid depth, and the gas flow rate.

For simplicity a single orifice of known diameter and length may be considered. As the bubble forms, its surface is constantly renewed with gas molecules. It develops a shape similar to an inverted pear. The bubble is then released and forms what may be described as an oblate spheroid with its horizontal axis greater than its vertical axis. As the bubble is not in equilibrium with its internal and external forces it passes through an approximately spherical state until its vertical axis becomes major. This is the only time when the bubble is longer than it is wide. Continuing to oscillate the bubble again becomes horizontal, although not quite as flat as when released. During this first oscillation the area to volume ratio of the bubble is a maximum. This, along with the extreme unbalance of forces on the elastic surface, may account for the rapid surface renewal and the high rate of oxygen transfer during and immediately after bubble formation.

The bubble continues to oscillate between a near sphere and an elongated ellipsoid in continually decreasing amplitude. Thus the transfer becomes less

as the bubble rises in the column. The so-called terminal velocity is then an average of the bubble's velocities as it changes shape. When compared with its release velocity the bubble seems stable. Theoretically then, a true terminal velocity is not realized until the internal forces balance the external forces on the bubble wall. The writers studied the shape of bubbles rising in a 70-cm tall column. At a constant gas flow, the bubble having an equivalent volume diameter of about 4.0 mm stabilized at a height of 45 cm. This numerical value has little significance but shows that the exposed surface area is a function of bubble age after release. With commercial diffusers, the surface area just above the diffusers may be 20% or more greater than that exhibited at mid-depth. If it is assumed that the rate of surface renewal is proportional to the degree of bubble instability, then the combined effect of increased surface area per bubble and bubble instability could account for the high rate of oxygen transfer at the lower depths and continually decreasing rates as the bubble rises.

Considering commercial diffusers involves additional factors which affect the rate of oxygen absorption. The bubbles are by no means uniform in size since their volume depends on the number and sizes of the orifices, liquid turbulence, and surface tension in the area of formation in addition to the parameters already mentioned. A number of small bubbles form on the diffuser's surface. A group of these bubbles combine to form a larger bubble that is capable of breaking loose from the forming device. The initial interfacial area is larger than after the smaller bubbles combine while attached to the diffuser plate. The resulting area to volume ratio of the bubble that is released is much smaller than it was during formation.

Surface tension varies over the bubble wall by virtue of its motion. This could account for the coefficient (K_L) being greater at its tip than at its sides. This is true even in the spherical range where surface drag is a minimum.

Fig. 1 summarizes the difference in rates of transfer throughout the bubble's life. The rate is high during formation and decreases with depth after release. A small quantity of oxygen is then absorbed as the bubble collapses on the water surface.

Bubbles which rise at Reynolds numbers greater than 300 and less than 4000 are ellipsoidal and are characteristic of the bubbles discussed in the preceding paragraphs. An oxygen bubble having a Reynolds number of 300 is 1.66 mm in equivalent volume diameter and has a velocity of 158 mm/sec at 25° C in 0.01 M KC1. The largest bubble exhibiting the highest Reynolds number observed was 4.22 mm in equivalent volume diameter and had a velocity of 322 mm/sec which yielded a Reynolds number of 1566 under the same conditions as described above. The range covered by these two extremes is representative of field conditions.

The effect of gas flow on bubble characteristics is three-phase. At low gas rates, bubble size is independent of the gas rate and the frequency of bubbling is directly proportional to gas flow rate. At high gas rates, bubble size becomes dependent on gas flow and frequency of formation remains constant.[1] There is a zone of transition between these extreme gas rates. Benzing[2] has found that at frequencies of less than 100 bubbles per minute per orifice the frequency of formation is directly proportional to gas flow. At frequencies of greater than 500 bubbles per minute per orifice, bubble volume becomes proportional to the gas rate while frequency remains constant. The writers have evidence, using a single orifice, that bubble volume remains constant up to 300 bubbles per minute while the frequency is directly proportional to the gas

flow. The corresponding gas flow was 6.5 cc/min through the single orifice.

These three phases are described schematically in Fig. 2. Area III is representative of the final Eq. (13) presented by the author which assumes $d_b \propto G_s^n$ and states:

$$K_L a \cdot V = C'' G_s^{(1-n)} h^{2/3}$$

Area I on the other hand, since $d_b = C$, may be represented by:

$$K_L a \cdot V = C''' G_s h^{2/3} \quad (1)$$

The transition zone, Area II, has the possible relationship:

$$K_L a \cdot V = C'''' G_s^{(1-n)} f h^{2/3} \quad (2)$$

where f = frequency of formation (number of bubbles per unit time).

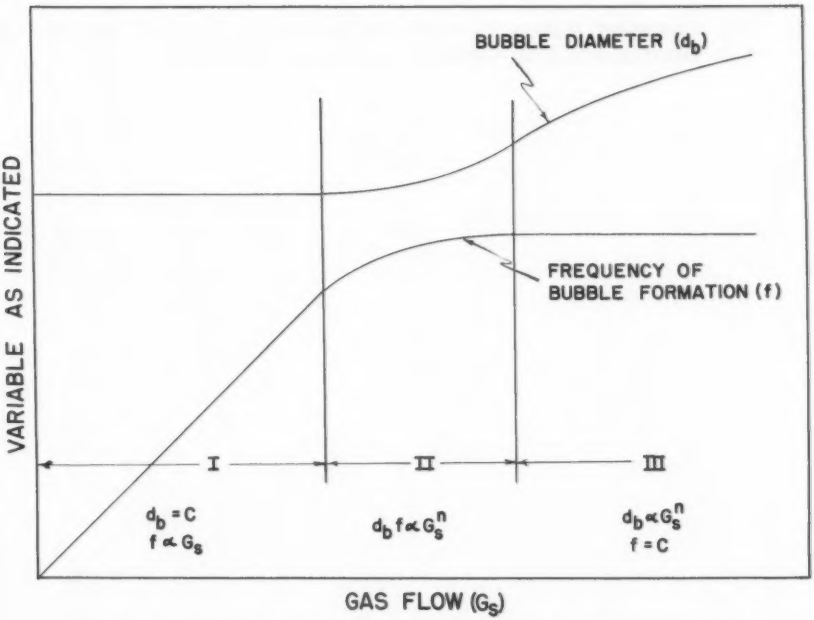

FIG. 2.—THE EFFECT OF GAS FLOW ON BUBBLE CHARACTERISTICS

The foregoing equations describing gas flow relationships show the gas flow exponent in all cases to be equal to or less than unity. As the gas flow per orifice increases, the system loses energy per unit gas flow because of the increase in bubble size. Therefore,

$$\left[\frac{K_L a \cdot V}{G_s}\right]_I > \left[\frac{K_L a \cdot V}{G_s}\right]_{II} > \left[\frac{K_L a \cdot V}{G_s}\right]_{III}$$

Up to this point the active geometry of the diffuser has been considered constant. However, as the pores are of unequal size only the largest orifices function at low gas flows. As the back pressure and gas flow increase the

smaller pores begin to produce bubbles. Thus a point is reached where all possible pores are emitting gas. After this point the geometry may be considered fixed. While approaching the complete pore activation it is possible for the gas flow exponent to exceed unity. This would in part explain the range of gas flow exponents being 0.86-1.35 in addition to the reasons proposed by the author.

While bubble aeration phenomena may be described empirically, studies of the behavior of individual bubbles are more likely to provide an understanding of the factors influencing oxygenation.

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2. "Low Frequency Bubble Formation at Horizontal Circular Orifices," by R. J. Benzing, Ind. Eng. Chem. 47 (1955), pp. 2087-2090.

PROCEEDINGS PAPERS

The technical papers published in the past year are identified by number below. Technical-division sponsorship is indicated by an abbreviation at the end of each Paper Number, the symbols referring to: Air Transport (AT), City Planning (CP), Construction (CO), Engineering Mechanics (EM), Highway (HW), Hydraulics (HY), Irrigation and Drainage (IR), Pipeline (PL), Power (PO), Sanitary Engineering (SA), Soil Mechanics and Foundations (SM), Structural (ST), Surveying and Mapping (SU), and Waterways and Harbors (WW), divisions. Papers sponsored by the Department of Conditions of Practice are identified by the symbols (PP). For titles and order coupons, refer to the appropriate issue of "Civil Engineering." Beginning with Volume 82 (January 1956) papers were published in Journals of the various Technical Divisions. To locate papers in the Journals, the symbols after the paper number are followed by a numeral designating the issue of a particular Journal in which the paper appeared. For example, Paper 2270 is identified as 2270(ST9) which indicates that the paper is contained in the ninth issue of the Journal of the Structural Division during 1959.

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JANUARY: 1892(AT1), 1893(AT1), 1894(EM1), 1895(EM1), 1896(EM1), 1897(EM1), 1898(EM1), 1899(HW1), 1900(HW1), 1901(HY1), 1902(HY1), 1903(HY1), 1904(HY1), 1905(PL1), 1906(PL1), 1907(PL1), 1908(PL1), 1909(ST1), 1910(ST1), 1911(ST1), 1912(ST1), 1913(ST1), 1914(ST1), 1915(ST1), 1916(AT1)[c], 1917(EM1)[c], 1918(HW1)[c], 1919(HY1)[c], 1920(PL1)[c], 1921(SA1)[c], 1922(ST1)[c], 1923(EM1), 1924(HW1), 1925(HW1), 1926 (PL1), 1927(HW), 1928(HW1), 1929(SA1), 1930(SA1), 1931(SA1), 1932(SA1).

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MARCH: 1960(HY3), 1961(HY3), 1962(HY3), 1963(IR1), 1964(IR1), 1965(IR1), 1966(IR1), 1967(SA2), 1968(SA2), 1969(ST3), 1970(ST3), 1971(ST3), 1972(ST3), 1973(ST3), 1974(ST3), 1975(ST3), 1976(WW1), 1977(WW1), 1978(WW1), 1979(WW1), 1980(WW1), 1981(WW1), 1982(WW1), 1983(WW1), 1984(SA2), 1985(SA2)[c], 1986 (IR1)[c], 1987(WW1)[c], 1988(ST3)[c], 1989(HY3)[c].

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MAY: 2014(AT2), 2015(AT2), 2016(AT2), 2017(HY5), 2018(HY5), 2019(HY5), 2020(HY5), 2021(HY5), 2022(HY5), 2023(PL2), 2024(PL2), 2025(PL2), 2026(PP1), 2027(PP1), 2028(PP1), 2029(PP1), 2030(SA3), 2031(SA3), 2032(SA3), 2033(SA3), 2034(ST5), 2035(ST5), 2036(ST5), 2037(ST5), 2038(PL2), 2039(PL2), 2040(AT2)[c]. 2041(PL2)[c], 2042(PP1)[c], 2043(ST5)[c], 2044(SA3)[c], 2045(HY5)[c], 2046(PP1), 2047(PP1).

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c. Discussion of several papers, grouped by divisions.

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PART 2

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Your attention is invited

NEWS OF THE SANITARY ENGINEERING DIVISION OF ASCE

JOURNAL OF THE SANITARY ENGINEERING DIVISION
PROCEEDINGS OF THE AMERICAN SOCIETY OF CIVIL ENGINEERS

DIVISION ACTIVITIES

SANITARY ENGINEERING DIVISION

Proceedings of the American Society of Civil Engineers

NEWS

January, 1960

NEW VISTAS IN SANITARY ENGINEERING

With this issue we inaugurate a new feature of the Newsletter. From time to time, we hope to bring the members of the Sanitary Engineering Division news of new frontiers, new horizons in man's efforts to control his environment. At the National Institutes of Health, a team of sanitary engineers and allied scientists have been developing new methods of controlling an environment -- the complex one involving medical research in all of its phases. The following section has been prepared by Donald L, Snow, F.A.S.C.E., Chief of the Sanitary Engineering Branch at the Institute.

SANITARY ENGINEERING IN MEDICAL RESEARCH

Sanitary engineering is an important research service at the Public Health Service's National Institutes of Health. Operating within the Institutes' Division of Research Services, headed by Chris A. Hansen, Sanitary Engineer Director, sanitary engineers and their colleagues in the sanitary sciences are discovering some brand new problem areas in this growing center for Federal medical research in Bethesda, Maryland.

Approximately 500 patients and 6,500 employees, and in excess of 1,000,000 laboratory animals of various species are housed in 22 major buildings on the Institutes' 300-acre tract. Maintaining "hospital-clean" conditions in the bulk of these buildings has drawn heavily on sanitary engineering services beginning with their early planning stages.

Protecting the water supply of the surrounding residential community, as well as the supply for patients and employees, from the diverse operations in over 1,500 individual laboratories usually has a new twist for each new laboratory facility built here. Laboratory water supplies "industrialized" with reduced pressure-zone backflow preventers are being used increasingly where conventional air-gap methods are limited. Deionized water supplies serving special washing equipment are typical systems requiring isolation.

Laboratory chemical waste disposal planning has involved the design of a unique waste chemical disposal plant now nearing completion. Facilities for

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solvent burning and chemical neutralization, crushing containers and personnel protection are included. The plant has been designed to dispose safely of a variety of highly reactive, toxic or flammable compounds typically used in medical research.

The economical and safe disposal of infectious wastes from medical research and hospital operations is another problem area confronting the sanitary engineering group here. To insure a completely safe chain of waste handling, the group has even developed specifications for plastic liners for GI refuse cans. Its earlier surveys of wastes produced in medical research now have been translated into dual, two-ton per hour municipal-type incinerators equipped with pneumatic operated grates, forced and induced draft fans and flue gas scrubbing towers capable of producing near odor-free stack effluents.

While atmospheric pollution from incinerator operations is being brought under control, the pollution of laboratory and hospital building intake air from chemical contaminants released from the building exhaust air outlets is now being intensively studied. This source of building air pollution is being identified increasingly in other medical research installations.

Central facilities for washing, processing and sterilizing laboratory glassware, washing animal cages, and other research-connected equipment find the sanitary engineers combining both industrial engineering and cleaning know-how in the layout of washing departments and the design of their specialized washing equipment.

Still another and a relatively new activity for them centers around engineering facilities and designing equipment for maintaining "germfree" animals. Both steel pressure vessels and non-pressure types of steel and plastic chambers, some of which were developed by the Division of Research Services group, are now in use for holding and breeding small laboratory animals in a bacteria-free state. Several years' experience confirms that the technology associated with "germfree" animals largely parallels the basic training and "know-how" of the sanitary engineer. One example of a clinical application of germfree technology involved a recent study of the bacteriological integrity of an artificial heart-lung machine.

Problems associated with operating rooms have also involved the Division's sanitary engineers in such diverse areas as operating room conductive floor protection and cleaning methods and air filtration and ventilation. Outside developments for the bacteriological sampling of air are now making it possible for the group to coorelate such factors as operating room air contamination with ventilation methods to a degree not previously possible.

Did You Know That

Robert O. Sylvester, Professor of Sanitary Engineering, University of Washington, Seattle, has been elected president of the Pacific Northwest Sewage and Industrial Wastes Association. Marvin W. Runyan, consulting engineer of Portland, Oregon, is now past president, while another former past president, R. Trumbull Smith, Seattle, is national director. Gilbert H. Dunstan, Professor of Sanitary Engineering, Washington State University, Pullman, was re-elected secretary-treasurer.

Israel W. Santry, Professor of Civil Engineering at Southern Methodist University has been elected president of the Texas Section, ASCE.

Lewis A. Young, Chairman Executive Committee, Sanitary Engineering Division, was recently elected president of the Georgia Section, ASCE.

Paul W. Eastman has been named Regional Program Director, Water Supply

and Pollution Control Program, Public Health Service Region IX, San Francisco, California.

Francis H. Kingsbury, Sanitary Engineer with the Division of Sanitary Engineering, retired effective August 31 after 47 years of service with the Massachusetts Department of Public Health. He started his career with the Division of Sanitary Engineering in 1912, and has held numerous important positions in connection with Department activities.

Since 1930 he has been directing the water supply activities of the Division of Sanitary Engineering. He served as technical advisor to the Legislative Commission on Water Supplies and was a member of the State Reclamation Board. He also represented the Commissioner of Public Health on the Water Resources Commission and the Weather Amendment Board.

He is the past president of the New England section of the American Society of the Civil Engineers, past chairman of the Sanitary Section of the Boston Society of Civil Engineers, past president and honorary member of the New England Water Works Association, and past director of the Massachusetts State Engineers Association. He is a diplomate of the American Academy of Sanitary Engineers.

SANITARY ENGINEERING MANPOWER

A comprehensive study, Sanitary Engineering Manpower, by Frank Butrico and Israel Light has recently been published by the Public Health Service. The summary is reproduced in its entirety because of widespread interest among sanitary engineers. Copies of the publication may be obtained from Frank Butrico, Chief, Engineering Resources Program, Division of Engineering Services, Public Health Service, Washington 25, D.C.

Summary

The approximately 4,000 sanitary engineers surveyed represent two-thirds of the estimated total number of such engineers in the country.

The median age of the Survey group is 44.5 years.

About 56 percent have the Bachelor's degree, and 40 percent have a graduate degree. Four percent are qualified as engineers through experience rather than a college education. Of those with a graduate degree, 37 percent have a Master's degree and 3 percent have a Doctor's degree.

About 70 percent (80) of all respondents holding the Doctor's degree, 75 percent (1,052) of those with the Master's degree, and 64 percent (1,385) of those with only the Bachelor's degree were all under 50 years of age. The high proportions of those holding graduate degrees reflect the increasing availability of graduate education in sanitary engineering, especially in the last decade presenting these data, 1946-1956.

Thirty-three percent of the engineers engaged in consulting and more than 40 percent of those in positions of administration or management hold a graduate degree. When grouped by kind of work performed, these two categories represent the oldest in age and those with the most years of professional experience. In view of the relative recency of widely available graduate curricula, these graduate degrees were undoubtedly added to considerable on-the-job experience, and thus reflect an engineering competence blended of rising standards and individual initiative.

Approximately the same number of sanitary engineers are to be found in the under-35 and over 55 age groups. However, at this time (1956) the replacement factor is not large enough in terms of the increasing attrition rate in the upper age groups and in terms of an engineering specialty which is expanding its area of responsibilities, functions, and duties.

About 60 percent of the respondents report 15 or more years of professional work experience. Another 20 percent have 8-14 years of experience, and 17 percent have 4-7 years of such experience.

Almost 66 percent of the respondents identify the fields of water supply, waste treatment, and water pollution control as their primary area of academic specialization or major area of professional experience. On the other hand, only 1 percent and half of 1 percent claim major specialization in air pollution and radiological health engineering, respectively.

Fifty percent of the surveyed engineers are employed by government, 27 percent are employed in business or industry, 15 percent are self-employed, and 5 percent are in the field of education. The remaining 3 percent are engaged in miscellaneous activities.

The 50 percent working in government are apportioned as follows: 15.5 percent are employed by States, 15.5 percent by municipalities, 8 percent by the Armed Forces, 5.6 percent by the Federal Government (civilian), and 5 percent by county government.

Fully 33 percent of the Survey group are engaged in administration or management of some kind. Twenty-seven percent report being in private practice or otherwise involved in engineering consultation. Sixteen percent are in development and design work. Sixteen percent are employed in inspection, production, and sales. Slightly more than seven percent are engaged in teaching and/or research.

Median income of the sanitary engineers (from principal employment) is $8,300. This varies, however, by type of employer. Thus, those employed by government receive $7,800;* employed in business or industry, $8,700; self-employed, $14,200; and teacher-engineers, $7,200.

Within government, the following medians are found: municipal, $7,900; county, $7,700; State, $7,100; and Federal, $8,800.*

Only 3,000 of the 4,000 respondents answered the question on additional income from professional services rendered. Of these, about 2,100 (71 percent) reported receiving no such supplemental income. Of the remaining 29 percent reporting some added income, 15 percent received under $1,000, 12 percent received between $1,000 and $5,000, and 2 percent earned more than $5,000.

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SANITARY ENGINEERING RESEARCH

THIRD RESEARCH CONFERENCE ON BIOLOGICAL WASTE TREATMENT

A three-day research conference, third of a series on Biological Waste Treatment, will be held at Manhattan College on April 20 through 22, 1960. Approximately half of the papers scheduled will present recent advances in the basic theories of biological oxidation and of oxygen transfer. The remainder of the program is concerned with new developments in the fields of aeration and biological waste treatment.

*These salary data do not reflect a 10-percent increase in the past 2 years for Federal employees.

Forty-two papers are scheduled in two parallel sessions. The authors include representatives of 17 universities and 4 governmental laboratories actively engaged in research on the nature of bio-oxidation and oxygen transfer.

The opportunity of scientific liaison and cooperation between research workers in American and abroad will be a special objective of this symposium. Eight papers from England, Holland, Sweden, Germany, and Japan have already been scheduled and others are being arranged. The mutual exchange of information and ideas with these scientists and engineers from abroad should provide a stimulating exchange of information and ideas.

Preprints of all papers will be distributed to registrants several weeks before the Conference in order to encourage profitable discussion. Each paper will be summarized in a 15 minute delivery with 30 minutes allotted for discussion from the floor and among the speakers. Conference Proceedings, including discussion, will be printed.

The 42 papers scheduled are divided into four categories:

A. Theory of Bio-oxidation
B. Recent Advances in Biological Oxidation
C. Oxygen Transfer Theory and Developments
D. Bio-oxidation of Sewage and Industrial Wastes

There will be two simultaneous sessions and ample time for full discussion will be scheduled.

RESEARCH PROJECTS AT SANITARY ENGINEERING CENTER

The following projects are currently underway at the Robert A. Taft Sanitary Engineering Center in Cincinnati, Ohio. Research in the radiological health field is not included since a comprehensive study of the nature and scope of research needs in this field is currently in progress.

Air Pollution

Full-scale study of dispersion of stack gases

Plant indicators of air pollution and air pollutants

Fluorine: A summary and evaluation of the problem of air pollution with fluorine and its compounds

Sulfur dioxide removal from flue gas

Incineration of combustible wastes

Engine exhaust gas analysis

Removal of air contaminants by catalytic oxidation

Development of quantitative field tests for particular classes of pollutants

Investigation of the efficiency of the freezeout method

Fundamental studies in the photochemistry at atmospheric processes

Quantative effects of meteorological parameters on air quality

Description and prediction of air pollution episodes through the meterological approach

Vertical air sampling over an urban area

Relationship of visibility to community air pollution levels and to other selected meterological parameters

Formulation of dispersion patterns over urban areas

The variation of surface concentration from elevated plume during diurnal fumigations

Fabric air filter design criteria studies

High temperature filter development

Incinerator design criteria studies

Cotton ginning operations air pollution studies

Development of improved smoke inspection guide

Auto exhaust studies

Field instrumentation for sampling and/or analysis of air pollutants in community atmosphere

Laboratory Instrumentation for sampling and/or analysis of air pollutants in community atmosphere

Nashville community air pollution study (engineering and meteorological phase only)

Development of analytical methods

Evaluation and application of carbon-14 analysis as a means of determining the source of atmospheric pollutants containing carbon

Field test kit for air pollution surveys

Detailed analysis of air contaminants

Investigations of reactions of simple and multicomponent systems of air pollution

Adaptation of physical methods for analysis of air pollutants to field use

Application of the particle-size spectrometer to air pollution research

A nonselective collector for sampling gaseous air pollutants

Study of the compression method of sampling gas and vapor from air

The role of exotic air in local air pollution

Development and evaluation of non-biological indicators for presence of air pollution

Auto exhaust chemistry studies

National air sampling network

Precipitation chemistry network

Evaluation and improvement of water treatment processes
(a) Removal of coliform organisms

(b) Improvement of chemical coagulation processes

(c) Small water supply systems

Fundamental factors in functioning of germicidal agents: Effect of free and combined available chlorine on indicator bacteria in polluted water and sewage

Role of water in transmission of viral diseases

Improved methods for determining bacterial water quality: Rapid methods for the enumeration of bacterial indicators of contamination

Role of fungi in environmental sanitation

Development of new or improved waste treatment methods for treatment of sewage and industrial wastes:
(a) Sewage treatment by stabilization ponds

(b) Complete anaerobic treatment of domestic sewage

Adaptation of selected microorganisms to degrade specific industrial waste components: Microbial degradation of alpha-conidendrin

Behavior of specific organic organic chemicals in treatment systems
(a) Persistence of commercially important specific organic chemical wastes in surface water
1. Vinyl compounds

(b) Study of the behavior of the same chemicals in conventional sewage treatment
1. Vinyl behavior in activated sludge
2. Vinyl behavior in anaerobic digestion

Improvement of procedure for recovery identification, measurement and evaluation of organics in polluted water

Identification, evaluation, and control of algae and other aquatic organisms causing water supply problems

Determination of water quality requirements for protection of aquatic life.
(a) Toxicological and physiological effects of wastes on aquatic life

(b) Practical methods for application of bioassays

Conservation and reuse of water

Effects of impoundments of water quality

Studies of stream pollution by radioactive wastes from uranium ore refineries

Effect of heavy metals on sewage treatment processes

Development of design principles for soil absorption systems for disposal of septic tank effluent

Improved methods for determining bacterial water quality:
(b) Evaluation of Enterococcus and Pseudomonas groups as indicators of pollution

Significance of protozoal and Metazoal organisms in water

Pollutional characterization of common significant industrial process wastes:
(a) catalytic cracking of petroleum

Evaluation and improvement of water treatment processes:
(d) Analysis of filter design criteria

Serological identification of waste components

Evaluation and improvement of water treatment processes:
(e) Removal of specific organic compounds

SIXTEEN SALINE WATER CONVERSION RESEARCH CONTRACTS

TOTAL $466,339

New research contracts, or contract renewals, awarded by the Office of Saline Water since July 1, 1959, total $466,339, the Department of the Interior announced recently.

According to Dr. A. L. Miller, Director of the Office of Saline Water, the research sponsored by these contracts is designed to uncover necessary scientific data to permit the development of new processes, or improvements on existing processes, in order to produce converted sea or brackish water at lower cost than is now possible.

The contracts and contract renewals are:

Battelle Memorial Institute, Columbus, Ohio; $62,540. Continuation of solar distillation developments and operation of a solar research station which includes experimental operation and development of various solar still prototypes.

Battelle Memorial Institute, Columbus, Ohio; $18,000. Additional research on rotary vapor compression distillation.

Carrier Corporation, Syracuse, N. Y.; $105,000. Continuation of development program on direct freezing process. Provides for experimental operation of 15,000 gallon per day pilot plant.

Cornell University, Ithaca, New York; $8,530. Continuation of research on direct freezing process using secondary refrigerant. Obtaining freezing and wash data for use in pilot plant design.

Curtiss-Wright Corporation, Princeton, N. J.; $14,327. Development and construction of improved flat tilted solar stills. Prototypes based upon previous OSW experimental design work for experimental operation at solar research station, Daytona Beach, Florida.

Franklin Institute, Philadelphia, Pa.; $2,355. Continuation of research on producing permanently hydrophilic surfaces on plastics films for solar stills.

Georgia Institute of Technology, Atlanta, Ga.; $21,190. Development of an improved solar still. Experimental evaluation of external condensation and dispersion of feed water in improving solar still yield and economy.

Lummus Co., New York, N. Y.; $4,000. Experiments to determine the application of atomized suspension techniques for the disposal of concentrated brines.

Othmer, Dr. Donald F., Brooklyn, New York; $8,000. Continuation of studies on vapor reheat flash distillation system.

Polytechnic Institute of Brooklyn, Brooklyn, N. Y.; $10,700. Experimental work required for vapor reheat flash distillation. Process design includes construction and operation of a one-stage evaporator spray condenser designed to simulate stages of a multistage unit.

Whiting Corporation, Harvey, Illinois; $80,000. Further experimental operation and research on long-tube vertical distillation experimental facility pertaining to scale and corrosion prevention.

Syracuse University Research Institute, Syracuse, N. Y.; $15,065. To investigate the feasibility of saline water conversion using gas hydrates.

Ionics, Incorporated, Cambridge, Mass.; $50,000. To determine the conditions controlling supersaturation in natural saline waters and thereby alleviate scaling in electrodialysis equipment.

Radiation Applications Inc., New York, N. Y.; $37,070. To synthesize, determine the essential physical and chemical characteristics and test ion-restraining membranes which are essential for the practical operation of the reverse osmosis conversion process.

Battelle Memorial Institute, Columbus, Ohio; $11,450. Initiation of a detailed study of corrosion of materials in hot sea water.

University of Oklahoma Research Institute, Norman, Okla.; $18,112. Fundamental study on electrical control of adsorptivity of porous conductors as a possible new conversion process.

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SANITARY ENGINEERING EDUCATION

NEW BUILDING AT WASHINGTON STATE

Washington State University has completed plans for a new engineering building, and construction is expected to start early in 1960. This building will house the entire department of civil engineering, bringing the department under a single roof for the first time. The sanitary engineering laboratories and offices, which serve both civil engineering and the Division of Industrial Research, will be housed in the new building. A Public Health Service grant of $52,000 has been received permitting the construction of additional facilities for an expanded research program in sanitary engineering.

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WATER SUPPLY AND POLLUTION CONTROL

Editors Note

In the final days of the 85th Congress, legislation was passed setting up two independent U. S. Government agencies --- both of limited life. These two agencies were the first created to develop an integrated plan for the development of land and water resources in specified river basins. The work of these two commissions is described in the following paragraphs. We hope as the work progresses to provide further details of the organization and work program of these study groups.

U. S. STUDY COMMISSION - TEXAS

One of the greatest problems encountered in past attempts to formulate comprehensive planning for water resource development has been the difficulty of coordinating the plans of Federal agencies with each other and with States and local interests. The U. S. Study Commission - Texas, established by Public Law 85-843, provides a new and untried form of organization, independent of any agency affiliation, to overcome these past problems.

The Commission has the assignment of formulating a comprehensive and coordinated plan for the development of land and water resources within eight major river basins and intervening coastal areas of the State of Texas. The basins are those extending contiguously from and inclusive of the Neches in the East to and inclusive of the Nueces in the Southwest. Upon completion of its assignment and submission of its report to the President for transmission to Congress, the Commission will automatically pass out of existence.

Planning has been divided into two stages. The first is the collection, assembly and evaluation of basic data and information. The second is the planning and development of a comprehensive and integrated plan for the maximum beneficial utilization of the ground and surface waters within the area of study.

To facilitate first-stage planning, collaboration groups have been established consisting of representatives from seven State and 12 Federal agencies generally responsible for gathering basic data and information. Each group operates under the chairmanship of a member of the Commission staff. The groups are charged with responsibilities in the areas of land use and treatment, surface-water hydrology, ground-water hydrology, water quality, municipal and industrial water requirements, irrigation, hydro-electric power, navigation, recreation, fish and wildlife, flood damage, sedimentation, drainage, and basic projects data.

Texas is an area that has been subjected to considerable study through the investigations and analyses of many local, State, and Federal projects that have been proposed and planned. Much data have been accumulated and one of the greatest problems is its collection, dissemination and evaluation. Collaboration groups, comprising representation from State and Federal agencies concerned, review and analyze the available information and recommend ways and means of developing it as the basis for second-stage planning. Following this procedure, the Bureau of Reclamation has been assigned the task of compiling basic hydrologic data in accordance with criteria set by the Commission. Similarly, the Corps of Engineers is making a study of flood hydrology and is preparing a report on main stream areas subject to flood damage together with the estimates of annual flood losses. The Soil Conservation Service has underway a study of upstream flood damage and of protective works necessary to control such damage. This same agency is also preparing a report on potential land drainage improvements and is making an inventory of present and potential irrigation. The Bureau of Reclamation in conjunction with the Public Health Service is undertaking the preparation of a report on projected water requirements for municipal and industrial purposes. These and other similar studies which will be prepared in accordance with uniform standards are necessary to collect and compile basic data for plan formulation.

The primary purpose of the proposed plan will be to supply projected municipal and industrial water requirements for the year 2010, integrating therein all other aspects of multipurpose development including irrigation, hydroelectric power, navigation, flood control, recreation, and fish and wildlife

conservation. In undertaking the second-stage planning, again the facilities of the Corps of Engineers and the Bureau of Reclamation will be used to the fullest extent. The special talents of State and the Federal agencies will be brought into the study to assure comprehensive consideration. As each river basin is being considered, State river authorities and similar local entities concerned with consumption and control of water of streams will be consulted. Finally, a series of public hearings will be held in order that all citizens and interests of the area will have adequate opportunity to present views and ideas.

ASCE is represented both on the Commission and on the staff. George R. Brown, Executive Vice President, Brown & Root, Inc., is Chairman of the Commission whose membership includes Harry P. Burleigh, Area Engineer, Bureau of Reclamation; Hubert S. Miller, Vice President & General Manager, Trinity Improvement Association; and Brigadier General William Whipple, Division Engineer, Corps of Engineers. The staff ASCE membership includes Charles D. Curran, Executive Director; Rolland F. Kaser, Chief Planning Engineer; Charles S. Stevens, Planning Engineer; W. Bion Moore, Chief Planning Specialist; Paul W. Reed, Water Quality Specialist; Everett W. Rowland, Chief Hydrologist; George E. Townsend, Hydrologist; Michael Spero, Civil Engineer; Charles B. Thompson, Hydraulic Engineer; and Donald G. Donegan, Civil Engineer.

U. S. STUDY COMMISSION, SOUTHEAST RIVER BASINS

The U. S. Study Commission, Southeast River Basins, was authorized by Public Law 85-850 on August 28, 1958, to provide for an integrated and cooperative investigation, study, and survey of approximately 90,000 square miles in the states of South Carolina, Georgia, Florida, and Alabama. This area covers the Savannah River Basin and most of the intervening area between it and the Perdido-Escambia River Basin. The purpose of this study is to formulate a comprehensive and coordinated plan for many enumerated purposes, including flood control; water supply; navigation; reclamation, irrigation and drainage; power and industrial development; soil conservation; forest conservation; fish and wildlife; recreation; salinity; and pollution abatement and protection of public health.

It is expected that this Commission will complete its investigation in about three years. In making the study, the Commission is striving to develop a plan to secure maximum benefit for region and the nation in conformance with the rights of the States and existing federal laws and policies.

Rather than employ a large staff, this Commission plans to utilize the services, studies, and continuing investigative programs of the several interested departments, bureaus, and agencies in both the federal and state governments. The Commission is composed of six members, one from each of the federal agencies: Department of the Army; Department of Commerce; Department of Health, Education and Welfare; Department of Agriculture; Department of Interior; and Federal Power Commission; four members, one from each of the four states, who have been specifically recommended by the governors of the states and one chairman selected by the President from the area at large.

The Commission members are: Chairman J. W. Woodruff, Jr.

Federal Agencies: Major General Frank M. Albrecht,
F. ASCE - Army

Howard W. Chapman, F. ASCE
Health, Education & Welfare

Walter A. Gresch - Interior

William E. Hiatt, F. ASCE
Commerce

Robert C. Price, F. ASCE
F. P. C.

John A. Short, M. ASCE
Agriculture

States:	James H. Hammond	South Carolina
	Ralph C. Hammond	Alabama
	Thomas A. Johnson	Florida
	Lester S. Moody	Georgia

Under the Act, responsibility for the work of the Commission is vested in the Chairman for (1) the appointment and supervision of personnel employed by the Commission, (2) the distribution of business among such personnel, and (3) the use and expenditures of funds. In carrying out his functions, the Chairman is being governed by the general policies of the Commission.

The address of the Commission and staff is P. O. Box 953, Atlanta, Georgia.

ASCE members on the staff include George E. Tomlinson, Executive Director; Harry W. Adams, Assistant Executive Director; Lester W. Angell; Richard F. Poston, Walter T. Wilson; Clarence M. Conway, Fred Larson; and Donald E. Whelan.

TAMPA BAY, FLORIDA - FRESH WATER LAKE

Rainfall and runoff data on the 130 square mile watershed above Courtney Campbell Causeway indicate the feasibility of changing the north end of Old Tampa Bay from salt water 14, -000 ppm chlorides) to fresh water (about 400 ppm chlorides). The project, long talked about by residents of the area, has received latest impetus through the action of a Hillsborough-Pinellas County Special Committee Studying Conversion of Upper Tampa Bay from Salt to Fresh water. The committee employed the services of consulting engineers to make a feasibility study.

Annual runoff from the watershed has been estimated to average 79,500 acre-ft or approximately 71 mgd (110 cfs). Rainfall on the surface of the lake approximates the inches of water loss through evaporation from the water surface (50 in.). It is proposed to construct a new and higher levee along the existing causeway. A mile-long strip, 1100 ft wide would be provided about mid-way. The spillway, lock, and bridge would be located in this strip. Areas would be provided for marinas, motels, restaurants and other associated recreation facilities. Income from the lease of commercial sites is expected to finance the estimated $7,000,000 cost of construction.

The lake level would be controlled between elevation 1.5 and 3.0 ft above mean sea level. Spillways would be designed for under-gate discharge to prevent salt-water inflow and to assist passage of salt-water outflow during the fresh-water fill period. Two small spillways would be located at each end of the causeway to avoid stagnant areas. According to the engineer's estimate it will take five years to complete the conversion from salt to fresh water once the project is completed.

Next stage in the project is the authorization by the counties for the preparation of detailed plans. Reported benefits include maintenance of sufficient depth of water to eliminate the unsightly and odoriferous mud flats thus encouraging the improvement and development of shoreline property; provide fresh-water fishing, recreation and boating; reduce and contain salt-water encroachment on wells around the lake; reduce damage due to high tides; and most importantly, provide a source of supply for an estimated 2.5 mgd of useable water for industrial and irrigation purposes.

NEW BILLS IN CONGRESS

Of interest to sanitary engineers are the following bills introduced late in the 1st Session of the 86th Congress:

H.R. 9150-- Commission on Food and Water Contamination.

Mr. David S. King (Utah) Establishes a commission to conduct scientific studies to determine the effects of various chemical additives for the treatment of water upon public health, food, and water supplies. Referred 9/8/59 to the House Committee on Interstate and Foreign Commerce.

H. J. Res.522-- Research Studies on Water Pollution.

Mr. Henry S. Reuss (Wis.) Directs the Secretary of Health, Education, and Welfare to carry out full and complete investigations of the following problems that relate to pollution abatement: methods of improving sewage treatment and disposal; effects of dumping oil wastes into navigable waters; effects of disposing of nuclear wastes in the ocean and navigable waters and methods for controlling water pollution caused by sewage and garbage from ships. Upon completion of these studies the Secretary would be required to formulate uniform laws for possible enactment by states and their political subdivisions for alleviating water pollution. The Secretary would also be expected to propose federal legislation deemed necessary to relieve the water pollution problem. Referred 9/8/59 to the House Committee on Public Works.

H. J. Res. 523-- Prohibition Against the Use of Fluoride In Water Treatment.

Mr. David S. King (Utah) Prohibits officers and employees of the United States from treating communal water supplies with fluoride compounds until a report from the Commission on Food and Water contamination shall have been submitted to Congress by the Commission. Referred 9/8/59 to the House Committee on Interstate and Foreign Commerce.

S.2645--Cooperative Worldwide Study of Radioactive Fallout.

Senator Harrison A. Williams, Jr. (N. J.) Authorizes the Surgeon General of the Public Health Service to undertake a cooperative worldwide study of radioactive fallout and other types of radiation hazard as they affect the lives and health of people. Referred 9/3/59 to the Senate Committee on Labor and Public Welfare.

H. R. 9235-- Susquehanna Watershed Commission.

Mr. Daniel J. Flood (Pa.) Creates a Susquehanna Watershed Commission for the Development and conservation of natural resources within the Susquehanna River watershed area. Provides for comprehensive planning of developments by the federal government in cooperation with local and state governments and citizen groups. The Commission would consist of nine full-time members including one person appointed by each of the following: Secretary of the Army, Secretary of Agriculture, Secretary of the Interior, Secretary of Commerce, Secretary of Health, Education and Welfare and the chairman of the Federal Power Commission. Three members would be appointed by the

governors of Pennsylvania, New York and Maryland. Referred 9/12/59 to the House Committee on Public Works.

STATE HEALTH OFFICERS' RECOMMENDATIONS TO PHS

At its annual meeting in October, the Association of State and Territorial Health Officers voted on over fifty recommendations proposed during the conference.

The Association, whose members include the chief executives of all State and Territorial health departments, made the following major recommendations to the Public Health Service in the field of environmental health.

Sewage Disposal by United States Vessels in Coastal Harbors

That the Public Health Service take the initiative with other Federal Agencies, such as the Navy, which operates vessels anchoring in coastal harbors to increase studies to improve sanitary conditions which occur from the discharge of large volumes of untreated sewage near communities which have arranged for treatment of their own sewage; and that the interested agencies support these studies with the necessary funds.

Vessel Pollution of Inland Water

That the Public Health Service take the initiative in formulating suggested uniform policies and procedures for control of vessel pollution as related to public water supply, recreation and other important uses of lake and river waters.

Toxicity of Herbicides

That the Public Health Service investigate and establish:

1. Acceptable practices for the application of land herbicides to safeguard swimming and drinking water;

2. Acceptable practices for application of safe residual concentrations of aquatic herbicides applied in streams, rivers, ponds, lakes, reservoirs, impoundments of contiguous swamp areas where this water may be used for swimming or for human consumption;

3. Analytical methods for determining the concentration of each herbicide for which a concentration or standard is suggested.

Sewage Treatment for Small Population Groups

That the Public Health Service sponsor a strong research program to develop more effective methods to treat sewage from population groups in the range of 50-500 persons.

Fluoridation of Public Water Supplies

That the fluoridation of public water supplies for the prevention of dental caries again be supported and encouraged.

SEWAGE AND INDUSTRIAL WASTES INVENTORY PUBLISHED

The 1959 Inventory of Municipal and Industrial Wastes Facilities in the United States has recently been published by the U. S. Public Health Service. This comprehensive publication -- nine volumes of concentrated factual data on facilities serving all communities and most waste producing industries having independent discharges -- is a cooperative activity of the various States and the Federal Government. This is the first published document since the 1945 edition.

The data contained in this publication represent the most authoritative single source of such information. Summary reports of the data have previously been published by the Public Health Service in its Publications No. 609 and 619, "Statistical Summary of Sewage Works in the U.S." and "Municipal Sewage Treatment Needs."

Copies of the Inventory, which is arranged in volumes by Department of Health, Education and Welfare Regions, are available from the Water Supply and Pollution Control Program, Public Health Service, Washington 25, D.C., or from the Regional Offices of the Public Health Service.

SEWAGE AND INDUSTRIAL WASTES INDEX AVAILABLE

The Ten-Year Index to SEWAGE AND INDUSTRIAL WASTES covering the period of 1949-1958 is now available.

The new Ten-Year Index is a companion to the previous Twenty-Year Index to the first 20 volumes of SEWAGE WORKS JOURNAL for 1928-1948.

Separate listings by author, subject, and geographic categories, along with full cross-referencing make this a complete, easy-to-use reference volume.

The 168-page volume is offered in a maroon buckram binding at $4.00 and in heavy paper cover at $3.00 and may be obtained from the Federation of Sewage and Industrial Wastes Associations, 4435 Wisconsin Avenue, Washington 16, D.C.

PROMOTING BOND ISSUES

Ted Sperling, Director of Public Information for the Metropolitan St. Louis Sewer District presented a paper on "Public Relations Aspects of Promoting a Bond Issue" at the recent annual meeting of the Missouri Water and Sewerage Conference.

This paper is a primer on managing a bond issue campaign. Spelled out in detail are the elements of a typical campaign with suggested approaches for marshalling forces of public opinion. The probability of defeat is also covered in detail with a lucid explanation of the need for developing a policy beforehand should such a contingency occur.

Sperling states, "It does take a skilled well-thought-out and hard-hitting campaign to pass a bond issue election for sewers or treatment. Unless a community is willing to accept this fact, it can not expect to win."

Copies of the paper may be obtained from Metropolitan St. Louis Sewer District, 901 Washington Avenue, St. Louis, Missouri.

NORTH CAROLINA WASTE CONFERENCE - APRIL 7 - 8, 1960

North Carolina State College will hold its Ninth Annual Municipal and Industrial Waste Conference, April 7 - 8, 1960, on the State College Campus in Raleigh.

For bulletins or further details, write the Division of College Extension, P.O. Box 5125, State College Station, Raleigh, North Carolina.

ILLINOIS SANITARY ENGINEERING CONFERENCE - JANUARY 27-28, 1960

Radiological Health Aspects of Water Supply is the subject of the Second Sanitary Engineering Conference to be conducted jointly by the Division of Sanitary Engineering, Illinois State Department of Public Health and the Department of Civil Engineering of the University of Illinois. This conference will be held at the University of Illinois in Urbana, on January 27 and 18, 1960. The First Sanitary Engineering Conference, held in January 1959, was on Water Works Safety. Further information may be obtained from Mr. William J. Downer, Assistant Chief Sanitary Engineer, Department of Public Health, Springfield, Illinois, or from Dr. Ben B. Ewing, Associate Professor of Sanitary Engineering, Department of Civil Engineering, University of Illinois, Urbana, Illinois.

Teague & Samson Named To Water Pollution Control Advisory Board

Dr. Russell Teague, Louisville, Kentucky and John S. Samson, Omaha, Nebraska will be two of the chief advisors to the Surgeon General of the U. S. Public Health Service in carrying out the Federal Water Pollution Control Program.

Their appointment to the Water Pollution Control Advisory Board for a three-year term was announced November 19, 1959, by President Eisenhower.

Dr. Teague is currently Commissioner of Health for Kentucky and is Secretary of the Kentucky Water Pollution Control Commission. He is a former chairman of the Ohio River Valley Sanitation Commission, and a current member of the Kentucky Planning Committee for the White House Conference on Children and Youth in 1960. He is also Chairman of the Environmental Sanitation Committee of the Association of State and Territorial Health Officers.

Dr. Teague received his medical degree from the University of Louisville School of Medicine in 1929 and his Master's Degree in public health from Johns Hopkins University in 1933.

Mr. Samson, a lawyer, has long been interested in conservation matters. He was one of the founders of the Omaha Chapter of the Izaak Walton League, and is Chairman of the League's State-wide Water Pollution Control Committee. He is also Chairman of the Nebraska Water Pollution Control Council.

In addition to Dr. Teague and Mr. Samson, the membership of the Board is as follows:

Dr. Leroy E. Burney, Chairman
Surgeon General
Public Health Service
Washington, D. C.

Mr. Irwin T. Bode
Former Director, Missouri
Conservation Commission

Mr. Frank E. Long
Member, Wyoming Stream Pollution
Control Advisory Council

Mr. William S. Wise
Director, Connecticut Water
Resources Commission

Hon. William F. Duckworth
Mayor of Norfolk, Virginia

Mr. Seth Gordon
Former Director, California
Department of Fish and Game

Mr. Anton Hulman, Jr.
Chairman, Indiana Flood Control
and Water Resources Commission

CONTRACTS APPROVED FOR SALINE WATER CONVERSION DEMONSTRATION PLANTS

Approval of contracts for architect and engineering services for the first three saline water conversion demonstration plants authorized by Public Law 85-883 were announced recently.

A $63,000 contract for the architect and engineering services for the long-tube vertical multiple effect distillation process demonstration plant to be constructed at Freeport, Texas, has been awarded to W. L. Badger and Associates of Ann Arbor, Michigan. This is an extension of an initial $50,000 cost-reimbursable contract for the preliminary design of the plant.

The Fluor Corporation of Whittier, California, has been awarded a $102,000 contract for architect and engineering services on the west coast multistage flash process demonstration plant.

Architect and engineering service responsibility for the electrodialysis process demonstration plant has been assigned to the Bureau of Reclamation, Denver, Colorado. The Bureau has been conducting research on electrodialysis processes, under contract with the Office of Saline Water, since 1956.

Selection of the fourth process for demonstration plant testing is not required by law until December 2, and the fifth process three months thereafter. The process selection board met November 4, to make recommendations for the selection of the fourth process.

AEC AND INTERIOR TO BUILD NUCLEAR-POWERED SALINE WATER CONVERSION PLANT

The Department of the Interior and the Atomic Energy Commission have signed an agreement for a cooperative project for the development of a nuclear-powered saline water conversion plant, Fred A. Seaton, Secretary of the Interior, and John S. Graham, Acting Chairman of the Atomic Energy Commission announced recently.

Under the agreement, the Commission will design, construct and operate a 40,000 thermal kilowatt experimental low-temperature process heat reactor capable of producing saturated steam at pressures from 5 to 175 pounds per square-inch gauge. The Department of the Interior will design, construct and operate a saline water conversion plant which will use steam from the reactor to produce at least 1,000,000 gallons of fresh water per day.

The reactor will be of the pressurized water type and will be used to determine the economic and technical feasibility of nuclear reactors for producing process heat. It is anticipated that process heat reactors can also be used in manufacturing industries, such as those for the production of primary metals, glass and cement, and petroleum, coal, chemical, food and paper products.

The saline water conversion plant will incorporate advanced concepts of the multistage flash distillation process designed to demonstrate the reliability,

engineering operating, and economic potentials for sea water conversion.

The combined facility will be located at Point Loma, San Diego, California. Estimated cost of the reactor is $4,000,000 and estimated cost of the conversion plant is $2,000,000.

BRACKISH WATER CONVERSION PLANT SITES IN THE NORTHERN GREAT PLAINS INSPECTED BY BOARD

Six cities in the Northern Great Plains have been selected for further consideration as a site for one of the two brackish water conversion demonstration plants authorized by Public Law 85-883, Secretary of the Interior Seaton recently announced.

The cities are Lincoln, Nebraska; Eureka, Miller, and Webster, South Dakota; Ellendale and Devils Lake, North Dakota.

Twenty Northern Great Plains' cities had asked to be considered as a site for the conversion plant authorized for that area. Based on their engineering judgment, members of the Board evaluated information obtained from the cities proposing sites by a rating system which compared technical factors (62%), demonstration value (24%), and assistance offered (14%).

Members of the Site Selection Board are: Sheppard T. Powell, Baltimore, Md., chairman, a mechanical and chemical engineer with over 35 years of experience as a consultant on water problems. Lewis S. Finch, Indianapolis, Indiana, Vice-President and Chief Engineer, Indianapolis Water Company, and immediate past President of the American Water Works Association. Dr. Wilburn C. Schroeder, University of Maryland, a professor of chemical engineering and a consultant on engineering and water problems.

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NUCLEAR ENERGY

CALIFORNIA RADIOLOGICAL HEALTH PROGRAM ESTABLISHED

A five-point radiological health program incorporating registration of all sources of ionizing radiation and total environmental surveillance of exposure of the population to radiation in air, water, and food has been established in the State Department of Public Health. The program went into effect on September 19th when the California Atomic Energy Development and Radiation Protection Law became effective.

The program will cover these five major points:

Registration

All sources of ionizing radiation will be registered with the State Department of Public Health. This registration will provide to all state agencies information as to location, nature, and quantity of sources of radiation, including X-ray machines, and other information to assist in assessing the present potential exposure of the population to sources of radiation at points of use.

Environmental Surveillance

Environmental surveillance will include a continuous program of assessing

the levels of radiation in air, water, food and other environmental media. The program, in cooperation with many state and local agencies, encompasses the routine collection and measurement of some 5,000 samples annually of air, rain, snow, water and the various elements of the human food chain on land and in the ocean. Routine samples containing gross amounts of radioactive materials which exceed the recommended maximum permissible concentration will be further examined to determine their specific isotopic or radionuclide content. All measurement will be done in the department's Sanitation Laboratory. Information obtained will be made available to all official agencies.

Medical Use of X-ray

The department will study and attempt to minimize the problem of genetic radiation dose to the population from the use of medical X-ray equipment. Use of X-ray in the medical and dental fields is currently conceded to be one of the major sources of X-ray exposure to the population.

Radioactive Waste Disposal

In the spring of 1958 the State Department of Public Health, in conjunction with the State Departments of Industrial Relations and of Fish and Game, entered into voluntary agreement with waste disposal firms to dispose of radioactive wastes in the Pacific Ocean at depths of at least 2,000 fathoms (12,000 feet) as a means of protecting the ocean food chain from contamination. This is a higher factor of safety than is required by the Atomic Energy Commission.

The policy on ocean disposal is now being reviewed with the AEC under the leadership of the new Coordinator of Atomic Energy Development and Radiation Protection. The department will assign inspectors to each ocean disposal trip. Disposal of such wastes by land-fill methods is also under active consideration, and all such operations will be closely supervised by the department.

Tracer Studies

All studies using radioactive tracers will be reviewed by the State Department of Public Health. The Atomic Energy Commission currently is withholding license for tracer studies until clearance is obtained from this department.

Three large scale tracer studies involving many curies of radioactivity have already been carried out in California, and other large scale studies are being proposed.

Administration

In order to carry out the new program, a total of 31 full-time positions have been included in the department budget of the current fiscal year. The director has authorized the immediate filling of 14 of these positions to form a core staff for the radiation program and its supporting laboratory. While the core staff may eventually operate at the bureau level, it is at present attached to the director's office. The laboratory will operate as a branch of the Sanitation Laboratory.

The core will co-ordinate the entire departmental radiological health program, and each department bureau will carry out that portion of the program which would normally fall into its field of activity.

Co-ordination With Other Agencies

The comprehensive fact-finding program envisioned by the department will require far more resources than those of this department. The co-operation of state and local agencies will be needed for carrying out the program. Since local health departments share public health responsibilities with the State Department of Public Health, the department will offer technical training and assistance to enable them to participate in many aspects of the radiological health program.

In order to insure co-ordination in this field of the activities of the various state and local agencies in California, a new position has been established in the Governor's office. This is the position of Co-ordinator of Atomic Energy Development and Radiation Protection, to which Colonel Alexander Grendon has been appointed.

UNDERGROUND RADIOACTIVE WASTE DISPOSAL

A conference jointly sponsored by the U. S. Atomic Energy Commission and the Sanitary Engineering Research Laboratory of the University of California, and concerned with the ground disposal of radioactive wastes, was held recently. The attendance included persons from France, Belgium and Canada, as well as representatives from the major U. S. nuclear laboratories. The problem under discussion stems from the fact that nearly all chemical processing plants handling used fissionable materials, as well as the larger research laboratories, produce large volumes of low and intermediate level wastes. In most instances, these wastes are chemically treated to remove and concentrate for storage a major fraction of the radioactivity. However, there often remains sufficient radioactivity in the effluent to prohibit discharge into nearby rivers or lakes. Under these circumstances, discharge to the earth may represent an interim solution and possibly even a final one.

At several of the sites represented at the conference, ground disposal, as currently practiced, is definitely an interim measure. Although no hazards have developed thus far, the local geology is often unsuited to ground disposal as a long-term disposal method. In any situation where it is necessary to contaminate meteoric waters, it must be expected that long-lived radionuclides may ultimately find their way into surface streams or into wells used for domestic and industrial water supply. On the other hand, the Hanford, Washington, site offers a geology permitting essentially permanent retention in surficial soils. At Hanford, a 200 to 300-foot dry surface formation, together with a low annual rainfall, makes possible extensive ground disposal operations with only negligible ground water contamination.